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PROCEEDINGS

OF THE

ENGINEERS' CLUB

OF

PHILADELPHIA.

ORGANIZED, 1877.

VOL. XII.

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Geo. C. Webster

Elected President, January 19, 1895, for the Eighteenth Year of the Club, A. D. 1895.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit is given the PROCEEDINGS.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XII.] APRIL, 1895. [No. 1.

ANNUAL ADDRESS

OF

JOHN C. TRAUTWINE, JR., Retiring President.

Delivered January 19, 1895.

MY immediate predecessor, Mr. Birkinbine, in his address as retiring President, departed from the usual manner of presidential addresses by confining his remarks chiefly to matters concerning our own city. Believing this example altogether worthy of imitation in the Engineers' Club of Philadelphia, I venture to follow it.

In one respect, however, I shall depart from the precedent thus established. Feeling that Philadelphians, as a rule, are too modest about their native city, Mr. Birkinbine devoted himsely chiefly to giving us an idea of the extent and importance of the city and of its resources, and I feel that he has performed this task so thoroughly, and has established the fame of our city upon so firm a basis, that I can well afford to devote myself to the humbler task of acting as historian of the city's engineering progress during the year just past. I shall, therefore, confine myself chiefly, though perhaps not strictly, to the unfolding of a plain,

unvarnished tale of this period of our city's history, presenting to you such facts as I could obtain by correspondence and by personal interview.

In spite of my best efforts, this report must, in the nature of the case, be incomplete and unsymmetrical; matters of great moment being, perhaps, treated slightingly or entirely overlooked, while others of minor importance may be dwelt upon at unnecessary length.

The Engineers' Club of Philadelphia.

Of all matters of local engineering interest, none, perhaps, is more immediately and vitally interesting to us than the welfare of our own Club, and it is proper, therefore, that we should first glance rapidly at the position maintained and the progress made by it in the year just past.

During several successive years, the progress of the Club has been constant and rapid, so that each succeeding president has had the good fortune to preside during a year in which the Club has registered a high-water mark.

Thanks to the intelligence, the fidelity, and the energy of your Board of Directors, my own experience in the presidential office has formed no exception to this. As you will see by the diagram thrown upon the screen, our membership during the year has just about held its own; but the average attendance at the meetings, which had steadily increased during the last three or four years, has made its most notable increase during 1894, when it reached the unprecedented figure of 73.

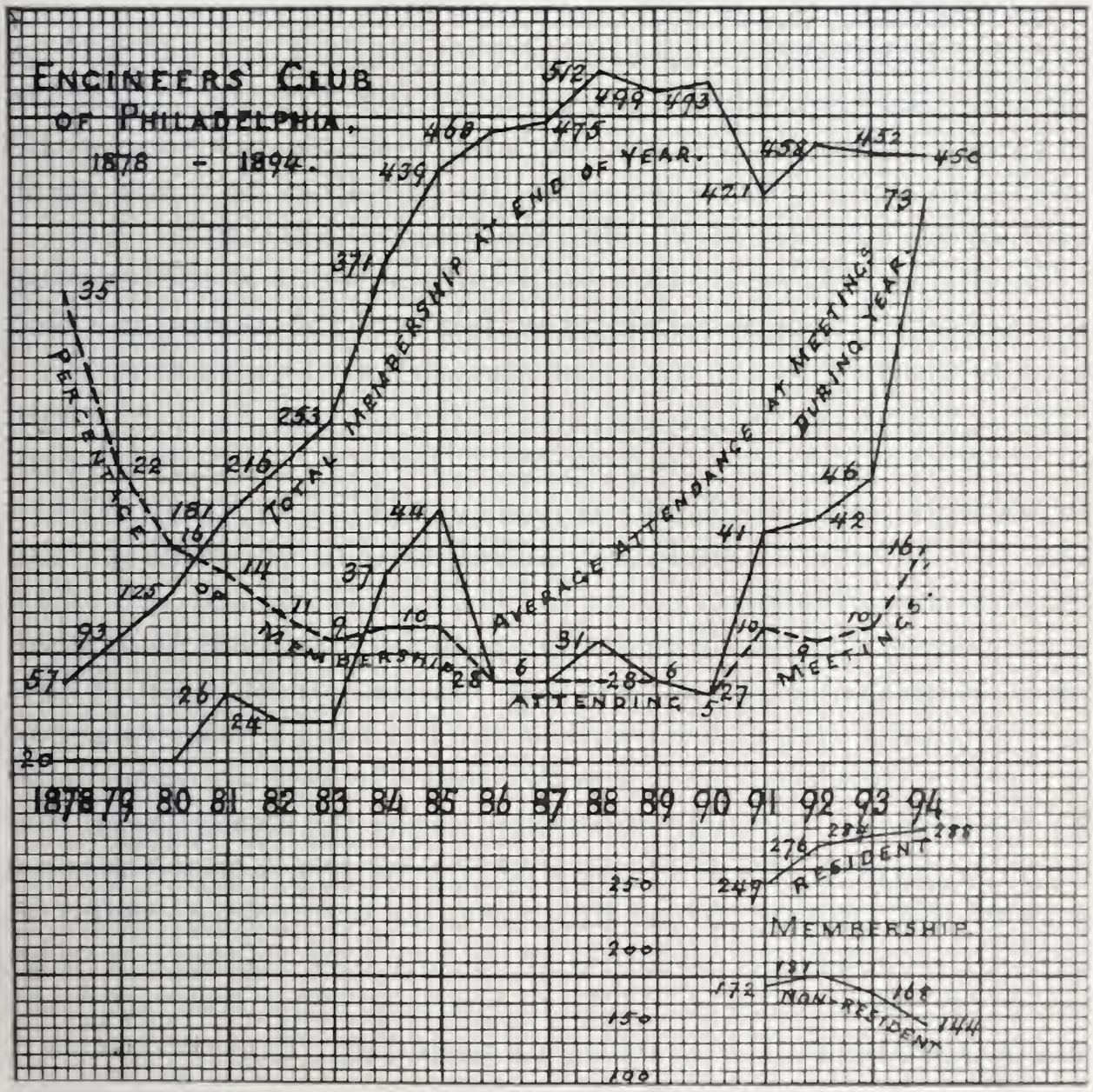
It is only proper to remark, however, that in congratulating ourselves upon this very large attendance we must bear in mind that:

(1) While the figures for each year include the visitors who favored us with their presence, that for 1894 includes perhaps a larger number of these than usual; your officers and directors having felt that in no way could the interests of the Club be better promoted than by inviting to our meetings those who, we felt, should belong to the Club.

(2) All of our estimates of attendance are based upon the counting of heads by the Secretary, an operation necessarily at-

tended with much uncertainty, especially when the attendance becomes large.

This suggests an idea which I brought forward years ago, but which was then considered impracticable, namely, that there should be kept, at the entrance door on meeting evenings, a book in which both members and visitors should, upon entering, be



requested to register their names. This is the practice with the American Society of Civil Engineers, and there would seem no good reason why something of the kind might not be inaugurated here. It would at least obviate the disagreeable necessity of poll counting, and would render our estimates of attendance much more reliable.

If, however, it is thought that this method would impose upon our members and visitors more trouble than they would care to take, we might place, on a desk at the entrance, two boxes containing respectively cards of two different colors, one for members and one for visitors, and each person entering might be requested to take a card of the proper color and deposit it in a third box, thus registering his attendance.

By the report of the Board of Directors, which has been sent to you, a report rose-colored in more senses than one, you will see that the funding scheme proposed by past-President Spangler, and the increase in the Club dues, have cleared the Club of all indebtedness, and have left it, for the first time in many years, with an unencumbered working balance in its treasury.

The history of the sinking fund and the result of the increase of the annual dues, are striking evidences of the esteem in which our Club is held by its members, and of their loyalty to it.

The proposition for the creation of the sinking fund was submitted and adopted on the evening of October 7, 1893, and, before the close of that year, $1400 in loans and $152 in donations had been received, much the larger part of them on the evening when the plan was adopted.

In view of the prevailing and enduring business depression, the most sanguine advocates of the increase in the annual dues were prepared to see, as a result of the increase, a large falling off in our membership, and it was felt that the best we could hope for was that the loss in membership would be considerably less than one-third of the whole, so that the net result might be some gain to the treasury, or, at the worst, no loss. As a matter of fact, our membership list has held its own, and among the resignations received there is, I believe, scarcely one directly and certainly traceable to the increase in the dues. These two facts, I think, speak volumes for the standing of the Club in the eyes of its members.

A very important feature shown in the diagram is the ratio between the total membership and the attendance. Starting with a handful of members, most or all of whom must have been resident, and all naturally eager for the success of the undertaking which they had just inaugurated, we find, in the

first year, an average attendance of 35 per cent. of the total membership. Later on, after large accessions had been made to our non resident list, and even when the total membership was at its high-water mark, the percentage attending the meetings fell as low as 5. During recent years, however, the ratio has steadily increased until, in the year just past, it reached 16 per cent.

One cause of this increased percentage is no doubt to be found in the fact indicated by the two curves, representing respectively the resident and non-resident membership during the last three years, which is as far back as our records inform us on this point. It is a very significant fact that, while our non-resident membership has decreased (most of the resignations presented being of this class) our resident membership has correspondingly increased. When it is remembered that the dues of resident members are three times those of non-residents, the effect of this upon the Club treasury can readily be estimated.

Under the able chairmanship of Mr. Falkenau, the Committee on Information has presented during the year a very valuable and interesting series of papers, and to this is, of course, due, in great measure, the large average attendance during the year. Among these papers, the following were of special local interest:

The New Falls Bridge. By W. B. Riegner.
The New Building Law of Philadelphia. By F. H. Lewis.
The Pneumatic Postal Tube. By A. Falkenau.
Improvement of the Delaware River. By L. Y. Schermerhorn.
The Harrison Buildings. By W. C. Furber.
Philadelphia Highway Improvements. By George A. Bullock, Chief of Bureau of Highways,

and Mr. Geyelin's paper, on the turbines for the paper mill at Niagara, describes an important piece of work by a Philadelphia firm.

The Publication Committee, with Prof. Silas G. Comfort at its head, has distinguished itself by its masterly conduct of our Proceedings. These have been issued promptly, bringing all

our publications up to date. At the same time the Committee has kept its business eye upon the matter of advertisements, so that the PROCEEDINGS continue to be practically self-supporting, while their high standard of typographical excellence has been fully maintained.

As Secretary of the Association of Engineering Societies, I laid before the Club in October last an invitation to confer with this Association, in order to ascertain whether it was not advisable that the Club should become a member of the Association and merge its Proceedings with the Journal of the latter.

As citizens of the United States, we rejoice that the Union is strengthened by the co-operation of the State of Pennsylvania; while, as citizens of the latter, we recognize that the advantages resulting to it from its membership in that Union far outweigh any which might be derived from independent nationality.

Similarly, as an officer of the Association, I desired the co-operation of the Club; and I also desired, as a member of the Club, that it might share in the advantages of the Association, that our papers might be issued monthly instead of quarterly, that our members, instead of receiving only our own papers, might receive also those of the other Societies in the Association, and that our papers and PROCEEDINGS might be given a circulation many times greater than that which they now enjoy.

The sense of the meeting at which the proposition was made, was, however, so decidedly adverse to it that even the invitation to a conference was declined.

It remains for us, therefore, to continue our efforts toward upholding and advancing the very high character of our publication, which is admittedly without a peer among those of other local and sectional societies, and, if the invitation extended has no other result than to increase the pride of our members in our PROCEEDINGS and their loyalty to it, it will not have been made in vain.

The activity of the Finance Committee, under the chairmanship of Mr. Gill, is manifested in the radical improvement of our financial condition, to which reference has already been made.

The House and Membership Committees, with Messrs. Landis and Christie respectively, as chairmen, have been no less zealous

in the discharge of their important functions, while the Library Committee, over which Mr. Hartley has presided, has maintained, with commendable dignity, that masterly inactivity to which it has been condemned by our circumstances, and which we may hope to see replaced by better things in the not too distant future.

The second Club excursion was made to Reading, Pa., in June last. This has been frequently and ably described, and I will now remark only that I esteem it not the least of the honors which my presidency has brought me, that it was during my administration that the ladies, by their presence on this excursion, first participated in any of the functions of the Club.

Another most agreeable social feature of the year was the visit of the American Institute of Electrical Engineers in May. This institution held its annual meeting at our Club house, which had been placed at its disposal for the purpose, and a very enjoyable reception was tendered to its members under the joint auspices of this Club and of the electrical section of the Franklin Institute.

The 300th meeting of the Club was that of June 16th. It is most unfortunate that this fact was not discovered until after the meeting had been held, for it would very properly have formed the occasion for a fitting celebration.

It is with great regret that I acknowledge the complete failure of my efforts to have the meetings opened promptly at the hour announced. I can only turn over the task to my successor, expressing the hope that he will attain in this respect a higher measure of success than was accorded to me, and calling upon my fellow-members to aid him in this good work by taking their places a few minutes in advance of the stated time.

City Work.

Turning now from the affairs of our own household to those of the city at large, it seems most appropriate that we should take up first those branches of our local government by which the city conducts its engineering work, and which are, therefore, closely allied, by their nature, to the objects and interests of our Club.

The Bureau of Surveys.

Among these, none is so directly related to us as the Department of Public Works, and, among its various bureaus, that which stands closest to us is the Bureau of Surveys, over which your President-elect, Mr. George S. Webster, so ably presides.

It is with great pleasure that I quote as follows from a letter recently received from Mr. James H. Windrim, Director of Public Works, in reply to my inquiry as to the labors of his department during the year.

Referring to the Reading Railroad Subway, now under construction, he says:

"There has been no work devolving upon the Chief Engineer of Bureau of Surveys heretofore which has included the variety of engineering problems; the solution of a difficult and interesting system of drainage and sewer construction preparatory to the commencement of the other works; the maintenance of existing buildings affected; railroad engineering in the construction of the subway for roadbed with its retaining walls; the bridge structures; tunnel construction; and, not least, providing convenient connections between the railroad and the industrial establishments located on the line of the subway system."

Referring to the city work in general, he says:

"The many engineering problems under control of the city require capability, good judgment and business tact in the Chief Engineer to successfully carry out the responsible and important public business devolving upon the Bureau of Surveys. The city has in the present Chief Engineer, Mr. George S. Webster, a most zealous and competent officer."

Among the many important matters committed to the Bureau of Surveys and constituting its field of operations during 1894, that of greatest magnitude, and perhaps that of greatest importance, is the depression of the tracks of the Reading Railroad on Pennsylvania Avenue, a work undertaken in order to avoid the numerous grade crossings which have heretofore interrupted the traffic upon the streets crossing that road.

The plans for this work were signed by the Mayor, by Mr. James H. Windrim, Director of Public Works; Mr. George S. Webster, Chief of Bureau of Surveys; Mr. Joseph S. Harris,

President of the Philadelphia and Reading Railroad, and by Mr. John A. Wilson, Consulting Engineer of that road, on August 31st.

As shown on the lantern slides, the improvement involves the construction of a roadway having a minimum of four tracks and placed at an average depression of 25 feet below the street level. There will be an open cutting from Broad to Twenty-first Streets, 3,500 feet; a tunnel from Twenty-first to between Twenty-sixth and Twenty-seventh Streets, 3,000 feet, and another open cutting from this point to Parrish Street, 2,000 feet. The streets which have hitherto crossed the road at grade will be carried over it upon bridges of steel plate girders.

Very little change in alignment is involved, but, of course, the profile is very materially modified. The present line, running north from the Terminal at Twelfth and Market Streets, is practically level to a point near Thirteenth Street, whereas the new line begins to descend at the north side of Carlton Street in order to reach the new low level at a point 125 feet west of Broad Street. The entire length of the improvement is about 10,000 feet, or something less than two miles. The work is expected to require from one and a-half to two years for its completion, and to cost $6,000,000, the cost being borne equally by the city and by the railroad company. The maximum gradient upon the main line will be 2½ per cent., or 132 feet per mile, while, on the sidings, provided in order to give access to the manufacturing establishments along the line, the maximum gradient will be 5 per cent., or 264 feet per mile.

In order to drain the subway, an elaborate system of new low-level sewers is required. This consists of two sub-systems, each emptying into the Schuylkill at Callowhill Street. One of these extends westward along Callowhill Street, and the other northward along Twenty-fourth Street and northwestward along Pennsylvania Avenue. Each of them is something over a mile long, exclusive of numerous branches, and the maximum depth is from 40 to 50 feet. Shafts are sunk 250 feet apart. The tunnels for this work are now practically completed, and the laying of the brickwork has commenced. The entire cost of the sewers alone reaches nearly $500,000.

While this is the most important work for the abolition of

grade crossings ever undertaken in this city, much other and important work has been done by the Bureau for the same purpose during the year.

At North Penn Junction, where the North Pennsylvania branch of the Philadelphia & Reading Railroad crosses the New York division of the Pennsylvania Railroad at grade, the tracks of the former have been depressed and those of the latter raised. This work, which, like the Reading Subway, involves the construction and reconstruction of sewers, is now nearing completion. Besides the bridge carrying the Pennsylvania over the North Pennsylvania Road, there will be four highway bridges over the latter. The total cost of the improvement will reach about $300,000, of which the city is to pay two-thirds and the Pennsylvania Railroad Company one-third.

At Broad and Huntingdon Streets, where the crossing of Broad Street and Lehigh Avenue over the Norristown branch of the Philadelphia & Reading Railroad was practically completed in 1893, the bridge and its approaches have been paved by the Railroad Company during the past year.

Along the Philadelphia & Trenton branch of the Pennsylvania Railroad, between Tacony and Holmesburg, many grade crossings have heen abolished, the streets and roads being led under the railroad; while in other parts of the city many new streets have been opened for the sole purpose of avoiding existing grade crossings.

Another important work in charge of the Bureau of Surveys is the construction of a new bridge at the Falls of Schuylkill. Here a double-decked steel Pratt truss bridge is being built, to take the place of the old wooden bridge, which was abandoned only a few days before it was blown down. There will be three pin-connected spans of about 180 feet each.

The masonry is now practically completed, and the western span is being erected.

The mild steel for the superstructure, 5,000,000 pounds in all, is being furnished by the Edge Moor Bridge Works.

This is the second pin-connected bridge of mild steel throughout built by the city (the first being that carrying Oxford Street over the Connecting Railway), and is the first steel bridge built

across the Schuylkill River in Philadelphia. It will cost about $265,000, including the substructure and superstructure, except the roadway on the upper deck.

Mr. O. M. Weand, of Reading, a member of our Club, took the sub-contract for the coffer-dam, by means of which the piers were founded, and kindly extended an invitation to our members to visit the works, an invitation which, I fear, owing to the difficulty of arranging for concerted action, met with but limited acceptation.

The dam consisted of a timber crib filled with stone. The bottom section of the crib was trimmed to fit the rock bottom, and the entire dam was surrounded by sheet piling, which was also trimmed to fit the rock. Puddle was then deposited around the entire dam on the outside to a depth of about three feet, and packed against the sheet piling.

A 6-inch Andrews centrifugal pump, running at less than half speed and not more than half time, kept the water well under control.

The proposed new drawbridge at Gray's Ferry exists, as yet, only on paper. It will take the place of the ancient wooden drawbridge at this site, and will carry the Philadelphia, Wilmington & Baltimore Division of the Pennsylvania Railroad upon its lower deck, and a highway upon the upper deck.

A new plate-girder bridge has been built, at a cost of $30,600, to carry Forty-ninth Street over the West Chester & Philadelphia branch of the Pennsylvania Railroad, the Pennsylvania Steel Company furnishing the material.

Some progress has been made in the construction of the Midvale Avenue improvement, which will utilize the new Falls Bridge and will form a series of handsome drives connecting Germantown and its vicinity, on the east side of the river, with the Park and with Overbrook on the west. The intercepting sewer for this improvement has been built by the city, and a brick and stone bridge has been constructed in order to carry the Norristown branch of the Philadelphia & Reading Railroad over the avenue, and the avenue itself has been paved between that point and Ridge Avenue.

An important improvement at private expense has been made

in the northwestern part of Germantown, between Upsal and Carpenter Streets and between Germantown Avenue and Green Street, a district embracing the old Carpenter estate.

The improvement of what is unfortunately called the "slum district," lying south of Pine Street and east of Broad Street, although completed in 1893, is worthy of mention here on account of the great improvement effected by it in the sanitary condition of the district named. At a cost of $400,000, nearly eight miles of sewers were laid, and over a hundred streets and alleys were paved with granolithic or asphalt paving.

In addition to the very important sewer construction rendered necessary by the depression of the Reading Railroad Company's tracks as already mentioned, the Bureau of Surveys has constructed, during 1894, over twelve miles of main sewers and fifty-eight miles of branch sewers.

On Thirty-third Street, between Market and Sansom Streets, the old four-foot sewer, relieving the Market Street sewer and discharging into that in Marsden Street, has been replaced by one of six feet diameter. Its construction was attended by great difficulty, due to the network of tracks and wires at the crossing of Darby Road, and a number of breaks occurred. These caused much annoyance, both to the Department and to the railroad companies, but the work is now nearly completed.

Under the impetus due to an investigation by the Board of Health in the summer of 1893 about $250,000 were appropriated for the prosecution of the work on the intercepting sewer and its branches, and, under this appropriation, the Lincoln Avenue system, extending from Wissahickon Avenue to Carpenter Street in Germantown, the Dobson's Run sewer, from the Wingohocking sewer at Germantown Avenue and Bristol Street to Morris and Coulter Streets, were constructed ; while the Germantown Avenue sewer was extended from Cresheim Creek to Chestnut Hill, intercepting the sewage of Wissahickon Inn and that of the Deaf and Dumb Asylum at Mt. Airy. The Manayunk system was also extended.

In connection with the work on the intercepting sewer, the Bureau has undertaken and carried out an elaborate system of tests of cements, under the superintendence of Mr. Richard L.

Humphrey, member of the Club. About a thousand samples of cement have been tested, including twenty-five brands of Portland and seven of natural cements, and 8,500 briquettes have been broken. Particular attention has been given to tests of mortar from the mixing box, in order to test the material under conditions approximating as nearly as possible to those of actual service. The tests have not been confined to the requirements of the intercepting sewer or of the Survey Bureau, but considerable testing work has been done for other bureaus and departments.

The Survey Bureau has also under its charge the project for the widening of Delaware Avenue to a width of 150 feet from property line to bulkhead. Plans for this work have been prepared under the inspection of Major C. W. Raymond, the resident United States Engineer, and the new harbor line has been established. The scheme involves the extension of wharves to a length of from 500 to 700 feet between Moore and William Streets, a distance of four and one-half miles.

The Bureau of Highways.

At the meeting of November 17th, Mr. George L. Bullock, Chief of the Bureau of Highways, entertained us with an account of the recent work of that Bureau, which has under its charge 1,325 miles of streets and roads, and 35 miles of bridges, representing an aggregate value of $15,000,000.

I may remark briefly that, during 1894, 28 miles of new paving were laid, 17 miles of streets were repaved with improved paving, and 19 miles were newly macadamized. It is estimated that during the same year 110 miles of improved paving were laid by the passenger railroad companies, as against 50 miles in the three preceding years.

The work of repaving, of course, involved the extension and renewal of sewers, pipe lines, etc., by the city.

A scheme for a Boulevard, to extend from the City Hall northwestwardly to the approach of Spring Garden Street Bridge at the southeast corner of Fairmount Park, was vetoed by the Mayor, and the veto was sustained. In place of this it is now proposed to construct a Boulevard along the line of Wood and Carleton Streets, extending westwardly from Broad Street and then north-

westwardly, generally parallel with the tracks of the Philadelphia and Reading Railroad.

As illustrating the relative durability of granite and asphalt paving, it may be mentioned here that when the girders for the Bourse were hauled from Thirty-third and Market Streets to the site of the Bourse, on Fifth Street above Chestnut, crossing-flags and manhole covers were broken, and a rut from one-half to three-quarters inch deep appeared everywhere on the granite paving along the route, whereas no trace of the wheels was left on the asphalt paving around the City Hall. The girders weighed from twenty-eight to thirty tons each, and overhung to such an extent that about twenty tons came on the rear pair of wheels. The wheels had seven-inch tires.

In November last Common Councils passed an ordinance to provide for the widening of Callowhill Street from Delaware Avenue to Fourth Street.

The Bureau of Water.

The year just passed has been one of great activity for the Bureau of Water and for its Chief, Mr. John L. Ogden. Its principal work during the year was that on the now notorious Queen Lane Reservoir, the two basins of which cover an area of sixty acres and have a capacity of 350,000,000 gallons of water. The reservoir was begun on October 10, 1892, and completed in November, 1894. Water was pumped in on November 29, 1894, as a protection against frost. On September 10, Mr. William J. Andrews, sub-contractor, charged that portions of the work and material furnished were not up to the standard of the specifications, and a committee consisting of Mr. John A. Wilson, Mr. Adolph Feldpauche, and our fellow-member, Mr. Joseph J. de Kinder, was appointed to investigate the matter. The report was generally favorable to the contractors, but intimated that the reservoir must be considerably strengthened before it could be safely trusted with its entire volume of water. Prof. L. M. Haupt, at the instance of the Citizens' Municipal Association, made a further report, reaching nearly the same conclusions.

Some uneasiness has since been caused by leaks from the reservoir under the small head of water pumped in.

PENNSYLVANIA STATE LIBRARY

A new 150,000,000-gallon reservoir at Roxborough, completed in 1893, has been leaking also, and it was not until after a year's search that the leaks were located.

To supply the Queen Lane Reservoir, a pumping station is being erected near the east bank of the Schuylkill, a short distance below the mouth of Wissahickon Creek. It will contain four pumps, each of 20,000,000 gallons daily capacity, all triple-expansion vertical pumps, built by the Southwark Foundry and Machine Company, and costing in all about $300,000. They will receive their steam supply from a battery of twenty-four furnace-flue boilers of the marine type, now being put in by Messrs. Righter & Connelly, of Pittsburg, at a total cost of $84,700.

A small pumping station has been erected on George's Hill, to pump from the reservoir there into the new stand-pipe close by, and to supply the Thirty-fourth Ward, which embraces the western portion of West Philadelphia. Four boilers, built by the Edge Moor Works, will supply steam to two 3,000,000-gallon Worthington pumps, brought to this station from Fairmount. A stand-pipe, 150 feet high, is now being built by the Warden Manufacturing Company, of Germantown Junction.

A nearly similar plant is being erected at Roxborough for the high service required in that vicinity. Here, as at George's Hill, there will be four Edge Moor boilers, and these will supply steam to a 5,000,000-gallon Worthington pump, built for the Kensington Works and afterwards used at Spring Garden. In the stand-pipe, which is now being built, the water will stand at an elevation of 491 feet above city datum.

A 6,000,000 gallon double compound Southwark pump, built here in 1893, broke down in October, 1894, owing to its having been improperly set on its foundations. It is now again in running order.

A very important extension is being made at the Spring Garden Pumping Station, just north of the eastern end of Girard Avenue bridge. Here two new pumps, each of 30,000,000 gallons daily capacity, are being erected by the Holly Manufacturing Company, of Lockport, N. Y., in an extension of the building, prepared to receive them. The engines are vertical, triple-expansion, and will cost, together, $162,570. They are the largest pumps in

the city service. They will pump into East Park Reservoir at an elevation of 133 feet. The Spring Garden Works have for some time been raising more water than all the other city pumps combined, and their capacity, after this addition, will be 210,000,000 gallons daily.

At the Frankford Station a new vertical compound pump, of 15,000,000 gallons daily capacity, is being erected by the Southwark Foundry and Machine Works, to pump into the Wentz Farm Reservoir.

Up to October 31st, 1894, the Bureau of Water had laid, during the year, forty-six miles of pipe, including six miles of 48-inch pumping main, and had placed 500 hydrants.

The Bureau has as yet installed no filtration plant, but the subject is being so vigorously discussed that it would seem that our city must come to this in the not very distant future.

Thus far, no inconvenience has been experienced through the electrolysis of water pipes.

Increase of Water Supply.

Year by year, as the population of the city increases, the sufficiency of its water supply becomes more and more problematical, and the necessity for its extension more urgent. In summer the entire flow of the Schuylkill River is now pumped for the supply of the city. As is well known, the city authorities have for years been on the lookout for an increase of the present supply, and Mr. James H. Windrim, the present Director of Public Works, urges the impounding of the Perkiomen, Tohickon and other streams, and the bringing of their water to the city through a conduit supplying all reservoirs of an elevation not over 240 feet. The plan contemplates the purchase of the entire watersheds of the streams involved, and the restoration of the timber growth upon them.

The proposed dam upon the Tohickon is 110 feet high, and the stream will supply 71,000,000 gallons daily to the Perkiomen. On the latter stream there will be two dams, with a total capacity of 8½ billion cubic feet, or 64 billion gallons. The main aqueduct, 24½ miles long and 14 feet in diameter, and capable of transmitting 300,000,000 gallons daily, will extend from the Perkiomen Creek to Queen Lane Reservoir.

The Bureau of Street Cleaning.

Accepting in its widest sense the classic definition of civil engineering as "the art of directing the great sources of power in nature for the use and convenience of man," we may properly include, in the engineering work of the city, the humble but no less useful offices of the Bureau of Street Cleaning, presided over by Mr. Sylvester H. Martin.

An interesting feature in connection with this Bureau is the progress made during recent years in the matter of the cremation of garbage, a progress of which, I venture to say, the majority of our members are unadvised.

The first provision for the cremation of garbage was made in 1892, when it was provided that a crematory should be erected for the service of the First District, or that portion of the city between the Delaware and Schuylkill Rivers and south of South Street. The first furnace, which was of the Dowling pattern, consumed 25 tons daily, and was put in operation April 1, 1893, at Fifteenth Street and Washington Avenue; the second, of 75 tons, in June of the same year; and a third furnace, of the same make and with a capacity of 75 tons daily, was put in operation, during the summer, at Twenty-fifth Street and Sedgely Avenue. It burned successfully the garbage of the district north of Poplar Street and west of Broad. In 1894 a 200-ton Dowling furnace was erected at Richmond Street and Allegheny Avenue, and a 30-ton Vivartas furnace at Fifth Street and Wyalusing Avenue. Both of these have been in successful operation since April 1st.

At Twenty-fourth and Callowhill Streets and at Twenty-fifth and Dauphin Streets, the Illinois Reduction Company erected two "Best" furnaces, one at each site. This furnace is divided into three compartments and is provided with a blower for drawing off the products of combustion and returning them to the fire grate as fuel gas. These furnaces were started in April, but, after numerous changes, they were condemned as inefficient and were removed by the contractors. They were replaced by two Smith-Siemens furnaces, of 200 tons each, which have run successfully since October 10th. The present total daily capacity of the furnaces employed by the city is 800 tons, and the total daily consumption is less than 300 tons, for which the city paid the con-

tractors, in 1894, $300,000 for collection and disposal. The furnaces were erected and operated by the contractors. That at Fifty-first Street and Wyalusing Avenue has been offered to the city for $15,000, and the others at $50,000 each.

The Dowling is a reverberatory furnace using petroleum, which is forced into the furnace by steam jets.

The Vivartas uses coal, but oil is added in order to improve combustion and to avoid explosions. The Smith-Siemens is a regenerative furnace, fired with coal gas generated on the spot and fed to the furnace through underground flues.

The Electrical Bureau.

Turning to the Department of Public Safety, we find its principal engineering functions discharged by the Electrical Bureau. This Bureau began operations, under the title of the Police and Fire Alarm Telegraph, on April 19, 1856, under the charge of Mr. David R. Walker, who is still Chief of the Bureau. At that time Boston already had a fire alarm telegraph, and New York a police alarm, but Philadelphia was the first city to inaugurate a combined police and fire alarm system.

The equipment then consisted of 60 miles of telegraph wire, 16 police stations and 58 signal boxes. There are now 2,000 miles of telegraph and telephone wire, 30 miles of lighting cables, 41 police stations, and 800 signal boxes, besides 400 police patrol signal stations and 5,300 arc lights, all under the control of the Electrical Bureau. New York now has 2100 lights, Boston, 2000, and Chicago, 1400, so that our city boasts of a number nearly equal to the total of these three.

There are also, under the charge of the Bureau, 650 telephones. The Bureau has supervision of all electrical construction in the city, including that of the telegraph, telephone and passenger railway companies.

The lamps employed for lighting the city are owned by five companies, who supply them with currents through cables belonging to the city. For eight years Chief Walker has been endeavoring to persuade the city fathers to acquire a municipal electric lighting plant, but thus far without success.

City cables have been placed underground on Broad Street

throughout its entire length, on the north side of Market Street from Delaware to Schuylkill, and on several other streets.

During 1894 the wires on Market Street and those on the east side of Broad Street from the City Hall to Christian Street, on Christian Street between the two rivers, on Lehigh Avenue from Broad Street to Kensington Avenue, and on Fairmount Avenue from Broad Street to the Park, have been placed underground. A number of fire engines and station houses have been wired and fitted up for lighting, and some of them have been lighted. This service is rendered by the companies without charge, under their contracts.

The police boat "Stokley," and the fire boat "Stuart," which were placed at our disposal by the courtesy of his Honor, the Mayor, for the use of our French guests in 1893, have been equipped with complete electric lighting apparatus and with search lights of 6000 candle power. An electric launch has been fitted up. Its storage battery is charged from the dynamos of the "Stokley" and the "Stuart."

During the year the Fire Bureau established a water tower at 2110 Market Street.

The City Hall.

In the City Hall, under the direction of the present architect, Mr. W. Bleddyn Powell, considerable progress has been made during the year in the fitting up of the apartments and in rectifying the defects of the building as originally constructed.

Contracts were signed in July for fitting up twelve large rooms for the Courts of Common Pleas and the Orphans' Courts, besides numerous offices. Work on these rooms is now well advanced, and court-rooms Nos. 243, 246, 275 and 285, for the Common Pleas, and Nos. 425 and 426, for the Orphans' Court, are nearly completed.

Two groups, of four Otis hydraulic elevators each, are being installed, one in the southwest and one in the northeast corner of the building, and others will follow later on.

The Common and Select Council chambers and the Finance Committee room, together with several other committee rooms, are located in the fourth floor, on the north side of the building. Work on these rooms and their connecting corridors was begun

about the middle of August and is now well advanced. The rooms will be ready for occupancy by Councils by the first of March, 1895.

The greater part of the work of reconstruction and repair has been expended upon the tower and the parts immediately surrounding it. The great settlement due to the enormous load upon the tower has, as is well known, caused many unsightly cracks in its own structure, and, even more particularly, in the surrounding portions, where, in the nature of the case, the amount of settlement was less.

In the semi-cylindrical projection from the south face of the tower, the stairway, and the ramping arches carrying it, have been removed and the arched openings in the east and west side walls have been built in. After this work was done, steel wedges were introduced between pairs of granite blocks inserted for the purpose, and, by driving these wedges, the cracks in the walls above them were closed up. It is even asserted that a plumb line 238 feet long, suspended in the center of the tower, indicated that the axis of the tower had actually been deflected to the northward hy the operation of the wedges, the deflection causing a movement of $\frac{5}{16}$ inch in the plumb-bob.

The east and west walls of the northern entrance, just north of the corresponding walls of the tower itself, had suffered particularly by the settlement of the latter, those portions in connection with the tower walls being carried down, causing unsightly cracks between them and the portions remaining in place.

For the most part, these walls have been cut away from the tower walls, the dead loads upon them have been reduced, and steel wedges have been driven into the cracks, thus giving the upper portions a firm bearing upon the lower, in which no further settlement is now anticipated. The spaces in the cracks between the wedges have been filled in with cement grout.

The walls just mentioned separated the north entrance from two large rooms on its east and west sides respectively, the eastern one being that in which the model of the Centennial building was, until lately, exhibited. In each of the opposite walls of these rooms, *i. e.*, in the eastern wall of the east room, and in the western wall of the west room, was a large opening of

50 feet, spanned by a heavy wrought iron-truss. It was found that the ends of each of these trusses sustained a load of 260 tons each, distributed upon a surface of 18 square feet. Deeming this bearing insufficient, Architect Powell is walling up these openings, and the spaces between the members of the trusses over them.

A heavy brick wall just north of the tower and forming the south side of the north entrance, was found to serve no useful purpose, and its settlement had caused considerable damage to the surrounding portions. It has therefore been removed, and the crippled portions of the work in its neighborhood are being restored.

As originally constructed, many of the larger rooms were spanned by a single central girder, from which floor beams or joists extended to the side walls. Many of these girders, by sagging, have given evidence of insufficiency, and they have been reinforced by a system of trussing between the girders of two floors. Each of these trusses consists of three panels. The side panels are occupied each by a diagonal strut, while the central one is left open and is used as a doorway between the two compartments into which each of these rooms is thus divided. The truss thus formed, has, as will be seen, a depth equal to that of the story in which it is placed. Where it was not practicable to introduce such trussing, the original girders of I-beams have been removed, and much stronger plate girders have been substituted.

Flooring of Carnegie corrugated plates has been extensively employed instead of bricks or hollow tile arching, and has been covered with a concrete floor three inches thick, including the finished surface.

Everyone recently passing through the building must have noticed the cracks in the stone lintels at the east and west exits from the courtyard. These lintels have a depth of 27 inches, and an effective width of about 36 inches. They cracked, in each case, and nearly simultaneously, at about one-third of their length from one end. They have since been reinforced by granite segmental arches placed under them. After cracking, the lintels deflected $\frac{3}{8}$ of an inch, but they were jacked up before

the arches were inserted, until they were $\frac{1}{8}$ of an inch above their normal level.

The total weight of masonry in the tower, above the concrete level, 28 feet below the ground, is 62,768 tons. This portion is 337 feet high, about 70 feet square outside and 45 feet square inside. The masonry is surmounted by an octagonal prism, about 60 feet high, of wrought-iron columns, with diagonal and horizontal bracing. This portion has been in place for some years. The pyramidal portion, 115 feet high, has been put in place during the past year, and has been surmounted by the statue of William Penn, 36 feet 6 inches high, whose bearing, with relation to the points of the compass, was, for a time, a matter of spirited newspaper dispute. The top of the statue is 548 feet $1\frac{1}{2}$ inches above the ground. The structural iron work of the tower was designed by Mr. C. R. Grimm, M. A. S. C. E., for the Tacony Iron and Metal Works, and was erected by that company.

All architectural features of the tholus (or combined prism and pyramid), such as columns, pilasters, cornices, dormer windows, hips, etc., are made of cast iron, generally $\frac{1}{4}$ inch thick. All plain portions, such as the louvres in the eight panels of the pyramid, are of $\frac{1}{8}$ inch steel. This outer shell or cover is protected by copper plate of 14 ounces per square foot, and a final plating, consisting of an alloy of aluminum and tin, and weighing $2\frac{1}{2}$ ounces per square foot, is added for effect in color.

The total weight of iron and steel in the tholus is nearly 900 tons. The bronze statuary consists of four groups at the corners of the base of the pyramid, weighing about 25,000 pounds each, the eagles on the tops of the pediments about 8,000 pounds each, and the Penn statue at the apex, 54,000 pounds, a total of 186,000 pounds of bronze work.

The Penn statue, 36 feet 6 inches high, weighing 54,000 pounds, was subdivided into fourteen pieces for convenience in erecting.

The statue was erected by means of a temporary, four-sided, framed prism, of Oregon pine, about 14 feet on a side, and 75 feet high. The feet of the four corner posts were secured to brackets provided in the permanent structure, for the support of a balcony

intended, for public use, at an altitude of 482 feet and about 28 feet below the base plate of the Penn statue.

Struts and ties were omitted from one side of this frame, in order to permit the raising and lowering of a 50-foot boom, which was hinged to a stiffened strut about 40 feet from the bottom of the frame.

The highest point of the derrick frame or false work was 560 feet above the ground.

Fairmount Park.

Let us now turn to that monumental example of the evils of socialism, Fairmount Park, to which all contribute and which all are free to enjoy; where the idle, the thriftless and the dissolute share the public wealth equally with the industrious, the sober and the thrifty.

We tolerate socialistic methods in the construction and maintenance of our streets, of our bridges and sewers, of our water-works and harbors, and of our public schools, on the pretext that these are natural monopolies and that they could not be so economically and satisfactorily conducted by private enterprise, but we recoil with horror at the suggestion that the state or the city should distribute bread as it distributes water. How much worse, then, if we find the state or the municipality not only furnishing the bread, but buttering it, supplying not only the necessities of life but its luxuries, in the shape of pleasure grounds. Surely this is paternalism run wild.

Our fellow-member, Mr. Russell Thayer, as Chief Engineer to the Park Commission, has, during 1894, constructed the river drive on the west side of the Schuylkill from Belmont Water-Works to Girard Avenue at Thirty-fifth Street, a distance of 1½ miles, at a cost thus far of $75,000; and 250,000 cubic yards of material have been dredged from the river above the dam and deposited on the low-lying portions of the Park. The east-side drive has been telforded from near Columbia Bridge to Strawberry Mansion and the Diamond Street entrance.

Ten thousand dollars have been expended in the construction of the first section of a river wall on the west side of the Schuylkill, beginning near Fairmount lock.

Our fellow-member, Mr. William Wharton, Jr., has been actively pushing his plan for an electric road in the Park, the object of which will be to render its beauties more accessible, but at this date the scheme has not reached the stage of actual construction. It is proposed to begin operations with the construction of a road located chiefly upon the west side of the river, starting from Belmont and Elm Avenues, running northwestward along the latter avenue, skirting George's Hill on the west, and passing under Belmont Avenue by a tunnel, just south of the proposed Midvale Avenue. Thus far, the line is double-tracked, but here the two lines diverge, enclosing between them the high ground extending from Belmont Mansion on the southwest to Chamounix on the northeast. A double-tracked line runs from the eastern side of this loop across the proposed new bridge to the east side of the river under Strawberry Mansion, and to the Park entrance at Dauphin Street.

New Jersey Ship Canal.

Under an appropriation by Councils of $10,000, a survey has been made, by Messrs. L. N. Hutton and L. M. Haupt, of a route for a ship canal between the Delaware River at Bordentown and Raritan Bay, at New Brunswick. The field work of the survey was completed in November. Our fellow-member, Mr. L. Y. Schermerhorn, whose very interesting paper on the Delaware River improvement was presented May 19th, is a member of the commission appointed by the Mayor to study and report upon the project.

Harbor Improvement.

The same gentleman, as President of the American Dredging Company, has, as we all know, been vigorously prosecuting the improvement of the harbor by the removal of Smith and Windmill Islands and the rectification of the west shore of Petty Island. During the year 6,000,000 cubic yards of material have been dredged, and 8000 linear feet of wharves and revetments have been removed. From thirteen to sixteen dredges have been employed, and the maximum monthly output was 800,000 cubic yards. Two million cubic yards have been deposited upon the Government property at League Island, raising an area of 125

acres to a level 12 feet above mean low tide. This portion of the work is now nearly completed, and the entire work of the improvement of the port is about one-third done.

The U. S. Engineer Office in this city, under the charge of Major C. W. Raymond, expended, during the fiscal year ending June 30, 1894, $50,000 in surveys, examinations and repair of the dike at Bulkhead Bar, and $24,000 upon the Schuylkill River in repairs to pile and earthen dikes at the mouth of the river and in dredging. The depth of the channel over the bar at the mouth of the Schuylkill has been increased two feet, and is now 21.4 feet at mean low water.

U. S. Geological Survey.

Under the superintendence of Mr. Charles D. Walcott, whose very interesting address we heard at our last meeting, the U. S. Geological Survey has, during 1894, thoroughly revised the two maps of Philadelphia and vicinity, prepared some years ago, to a scale of one inch to the mile, giving special attention to the cultural features. The work has been done entirely by plane table, and is based on the triangulation of the U. S. Coast and Geodetic Survey. The maps are now in course of preparation.

Steam Railroads.

Turning now from the strictly socialistic or communistic works which we have been considering, to those of corporate bodies, which may be regarded as semi-socialistic, we notice, first, the operations of the steam railroads having their termini in this city.

The process of amalgamation and concentration, which for years has been so marked a feature of all our business life, has, notwithstanding the enormous increase in the plants of the railroads terminating here and in the business transacted by them, reduced their number to three.

The business depression of the last two years has, perhaps, sat more heavily upon the railroad interest than upon any other. As a consequence there is little to report on their behalf except a profound inactivity.

As a rule, the panic of 1893 witnessed a sharp and peremptory

stoppage of all work that could be stopped upon our great railroad systems, thus greatly lightening the task of the historian.

For the Pennsylvania Railroad we have to report only the project for a bridge across the Delaware River from Port Richmond, Philadelphia, to Fisher's Point, Camden, and even in this we are recording, not what has been done during 1894, but what may be done during 1895.

The bridge, as designed, will have three fixed spans of 533 feet each from center to center of end spans, and a draw span of 323 feet near the New Jersey shore. The plans contemplate a headway of 50 feet above the river, and this has been accepted by the Government engineers as satisfactory, although the city, as represented by some of its trade organizations, is disposed to protest on the ground of insufficient clearance for the smoke-stacks of river steamers.

The contract for the substructure has been let, and the piers will be of concrete faced with masonry.

The new terminal station at Broad Street was completed in July last.

The terminal station of the Philadelphia and Reading Railroad was finished in December, 1893.

So great has been the effect of the business depression upon the activities of our railroads, that the construction, by the Reading, of its Philadelphia and Frankford Branch, two and one-half miles long, stands out as almost the sole instance of steam railroad activity in or about this city. The line leaves the Philadelphia, Newtown & New York branch of the railroad at Crescentville, and reaches Frankford by a very circuitous route. The work was begun July, 1892, stopped from July, 1893, to March, 1894, and finished in July, 1894. There are no grade crossings.

The great work of the construction of the subway for the accommodation of the Reading Railroad Company's tracks on Pennsylvania Avenue, has already been described under the operation of the Bureau of Surveys.

Electric Railways.

Whether or not electricity is destined to replace steam upon our main lines of railway, there can be no question that the

enormous activity in the development of city and suburban electric lines forms a striking contrast with the depression which has marked the last two years in steam railroading. While these two years have been characterized by an almost total suspension of construction on steam lines, they have witnessed, especially in our city, a correspondingly great activity in the development of electric lines.

Until September, 1893, but one electric line, that on Catharine and Bainbridge Streets, was running in this city. In September, 1893, the Morris and Tasker Streets line was started, and the Thirteenth add Fifteenth Streets line was opened in December of that year. Practically, therefore, we may say that the trolley railroad system of Philadelphia, as we have it to-day, is the creation of the year 1894.

At the end of 1894, the several companies had mileages as follows:

Philadelphia Traction Company,	108	miles
Electric Traction Company,	70	"
People's Traction Company,	40	"
Hestonville, Mantua and Fairmount,	20	"

Making a total of say 250 miles, and this has been increased by the completion of over 20 miles during the two weeks of the current month.

The pioneer in the use of the trolley was the Philadelphia Traction Company, which, as will be seen by the foregoing table, has now the greatest trolley mileage in the city.

It is but a short time since Philadelphians were up in arms against the introduction of the trolley system, but so readily do we forget our opposition to innovations as soon as they have proved beneficial, that it may be well to quote briefly from an excellent description of the plant of this company, contributed by our fellow-member, Mr. Hermann S. Hering, to a recent number of the *Electrical World:*

"Two years ago there was the most strenuous opposition to the introduction of the trolley system into Philadelphia, when this company applied for the privilege. Mass meetings were held, petitions were circulated, councilmen were threatened and every effort made by the people to prevent this 'invasion of the

deadly trolley.' The Philadelphia Traction Company, however, fought long and hard, and finally, by means of a loop-hole in the charter of the Catharine and Bainbridge Streets line, and through their promises to build the road in the safest and best manner possible, and pave the streets from curb to curb, succeeded in obtaining the right to equip and operate this line by electricity. It was to be a 'model road' and show the people of Philadelphia what a good trolley road was, most of those who objected never having seen one. The feeders were all to be placed under ground, the trolley wire protected from wires falling across it by means of guard wires, neat iron poles were to be used, the street paved with asphalt, from curb to curb, the cars stopped at every street crossing and on the near side, to avoid accidents, and every precaution taken to further the successful operation of the road.

"The experiment was a thorough success and broke the ice of opposition, and since then permission has been granted to this company for the electrical equipment of all of its lines, and to the other street car companies as well. A contrast to the strong opposition of the people two years ago, was shown during the opening of a road with this new equipment recently. The first cars were greeted by the shouts of hundreds of people, who lined the route and gave vent to their enthusiasm with fire works and brass bands; banners were displayed with such phrases as 'Welcome Rapid Transit,' etc., and the officials who occupied the first car were showered with flowers by the ladies along the road.

"All of the car lines which have been equipped for electric traction have been obliged to follow the general plan of the first and so salled 'model road,' embodying underground feeders, iron poles, guard wires, and a new pavement from curb to curb of either asphalt or belgian block, according to the requirement of the department of Public Works of the City Government. Thus Philadelphia is being equipped with trolley roads of the safest and best character, and is also enjoying the benefits of newly paved streets, a great contrast to the historic cobble stones. This was undoubtedly due, to a large extent, to the determined opposition which the railway companies had to overcome, as experience in other cities shows that the

street car companies do not pave the streets and put the feeders underground of their own volition.

"The rapidity and thoroughness with which the roads of the Philadelphia Traction Company have been equipped and the stations constructed, and the success with which they have been operated from the start, reflect great credit upon the management of the company, but especially upon the skill and perseverance of the engineering staff, to whose ability and conscientious efforts this success is mainly due."

The company now operates lines on Catharine and Bainbridge, Morris and Tasker, Thirteenth and Fifteenth, Nineteenth and Twentieth, Twelfth and Sixteenth, Seventeenth and Nineteenth, Twenty-second and Twenty-third, Spruce and Pine, Chestnut and Walnut, Jefferson and Master Streets, and Ridge and Lancaster Avenues, besides branch lines to Forty-ninth Street, Darby, Manayunk, Haddington and Germantown.

The construction of the line last named involved that of a bridge under the Philadelphia and Reading Railroad at Wayne Junction, and one over the Chestnut Hill branch of the Pennsylvania Railroad at the crossing of Washington and Wayne Streets, Germantown. The latter bridge is now under construction, while the former is in operation.

Besides its 108 miles of electric railroad, the company still operates 34 miles of cable and 25 miles of horse railway, all of which will before long be equipped with electric motive power.

The cost per mile of the electrically equipped road, exclusive of stations, is about $30,000.

With one exception, this is the most extensive system operated by one company in the world, and it was the first large system to use underground feeders.

The company's four power-houses are located at Thirteenth and Mt. Vernon Streets, Thirty-third and Market Streets, Sutherland Avenue, and Thirty-second and Dauphin Streets. Their present total horse-power is about 12,000. The current there generated is carried by underground feeders to the insulated trolley sections.

The system comprises 1209 manholes of an average size of 5 x 5 feet, 425 feeder junction boxes, 15,000 poles of wrought-iron pipe, manufactured by Morris, Tasker & Company, Limited, im-

bedded in 5½ feet of Portland concrete. The rails used are 90-pound, side-bearing, steel girder rails, 9½ inches high, manufactured by Wm. Wharton, Jr., & Co. There are at present running 400 cars, most of which are equipped with two 25-horse-power motors. These cars find accommodation in ten car-barns. The car capacity, it is announced, will shortly be doubled.

The system of the Electric Traction Company is, in Philadelphia, the second in point of extent, comprising 71 miles of line, and embracing the Second and Third, Fifth and Sixth, Tenth and Eleventh, Lombard and South, and Lehigh Avenue lines. The Frankford Extension of the Fifth and Sixth Streets line has recently been equipped with trolley cars replacing the ancient steam dummies.

The three power-houses of the company are located respectively at 1543 Hutchinson Street, at 920 North Delaware Avenue, and at the foot of South Street, Schuylkill River. The company uses underground feeders and paper insulation. The electrical machinery was installed by the General Electric Company. The company uses 9-inch girder-rails, and compound curves with radii of 75, 50 and 35 feet. The 6 feet 6 inch wheel base just goes around these curves. During the year the company carried 41,000,000 passengers at a cost of $1,800,000, and with a profit of $100,000.

The People's Traction Company, with 40 miles of lines, operates chiefly the lines on Fourth and Eighth Streets, with its various branches, including those on Green Street, Fairmount, Girard, Susquehanna, Indiana and Germantown Avenues, with suburban lines to Germantown, Chestnut Hill and Jenkintown.

The power-house is located on Delaware Avenue above Green Street, with a coal-hoist tower on the west side of Beach Street.

The cars run by this company are exceptionally large, handsome and well lighted, and during the summer of last year these offered special attractions to evening trolley parties.

The Hestonville line, under the superintendence of Mr. A. Langstaff Johnston, operates lines on Arch and on Race and Vine Streets, and Lancaster Avenue, with an aggregate length of about 20 miles.

The power-house, located at Twenty-sixth and Callowhill

Streets, has four batteries, each of two 250-horse-power Babcock & Wilcox safety water-tube boilers, supplying steam to four tandem, compound, condensing Greene engines, rated at 500-horse-power each, and installed by the Provident Steam Engine Company. The switchboard was designed by Mr. Johnston, as was also the rail-bond used on the line, which is designed to give an exceptionally large area of copper contact. Johnson girder rails, 90 pounds to the yard, are used. The poles are insulated from the line by yellow pine plugs, painted with an insulating compound. It is intended shortly to extend the Lancaster Avenue line to Overbrook, on the line between Philadelphia and Montgomery Counties.

Elevated Railroads.

Even more thoroughly dead, if possible, than the work of construction on steam railroad lines, is that which was projected, and even begun, on the elevated railways, which it was at one time intended to erect in this city. A few sleepers were placed on Elm Avenue for the Market Street line, and about 100 feet in length of elevated railway were constructed on Front Street north of Arch Street for the Northeastern line, but no trace now remains of either of these enterprises.

Buildings.

Notwithstanding the paralyzing effects of the business depression, considerable activity has been manifested in the construction of new buildings in the city during the year.

The work upon the City Hall and the opening of the Pennsylvania and Reading Railroad Terminals have already been noticed.

Perhaps the most important of the buildings erected during the year is that for the Bourse, extending from Fourth to Fifth Streets between Market and Chestnut. I am indebted to Mr. J. A. Patterson, engineer of the building and member of our Club, for data respecting this building and for the illustrations from which the lantern slides were made.

The ground was broken for this structure October 16, 1893, the building was under roof November, 1894, and it is expected that it will be completed by October 1, 1895. It will contain 9,000,000 bricks, 55,000 cubic feet of stone work, and 3,200 tons of iron

work, which has been erected by the Edge Moor Iron Works. The building, of eight stories, or 130 feet, in height covers an area of 130 x 356 feet. It is not of the modern skeleton type, the walls being generally self-sustaining.

Among other important buildings which have been erected during the year, or which are now being erected, are the following:

The Fidelity Mutual Life Insurance Building, on Broad Street, above Arch, which covers an area of 137 by 60 feet, and will be thirteen stories, or 172 feet, in height. It will contain 4,500,000 pounds of steel, which is being put in place by the Edge Moor Company. The columns at the Broad Street front are carried on cantilever girders, weighing from 22 to 30 tons each. Up to the fourth floor the walls are self-supporting, while above that level they rest on the steel frame.

The A. C. Harrison Building, at Fifteenth and Market Streets, covers a space of 116 x 40 feet, and is fifteen stories, or 160 feet, in height. It is of the skeleton type and will require 2,000,000 pounds of steel, which is being furnished by the Edge Moor Company.

We must notice, also, the new Odd Fellows' Hall, at Broad and Cherry Streets, forming a striking architectural contrast with the Masonic Temple at Broad and Filbert Streets; the Boys' High School, now under way at Broad and Brandywine Streets, the corner-stone of which was laid by President Sheppard, October 20th; the C. C. Harrison buildings, at Tenth and Market and Tenth and Filbert Streets, described by Mr. W. C. Furber in his paper of June 16th; the Lorraine Apartment House, at Broad Street and Fairmount Avenue, the similar structure at Thirty-second and Chestnut Streets, and the handsome Mercantile Club, on Broad Street above Master.

It is expected that, during the coming spring, work will be begun upon the projected dormitories for the University. They are to occupy the space between Spruce Street and Woodland Avenue upon the south and Pine Street on the north, and will extend from Thirty-sixth Street on the east to beyond Thirty-eighth Street on the west. Mr. John Stewardson, the architect, has visited the Universities of Oxford and Cambridge, of England, and of Princeton, Yale and Harvard, of this country, in order to acquaint himself with the best prevailing practice.

Manufacturing Establishments.

Let us now glance hastily at those private and corporate manufacturing establishments for which our city has so long been famous.

Every engineering visitor to Philadelphia desires, first of all, to visit Baldwin's and Cramp's, those two world-renowned establishments, devoted to the interests of transportation by land and water respectively.

Owing to the prevailing depression, which, as already remarked, has been especially fatal in its effect upon railroad operations, the output of the Baldwin works has been but about one third of the normal. Up to May, 1893, these works had turned out 13,420 engines, of which 6,571, or nearly one-half, were built in the ten years immediately preceding that date, but during 1894 only 313 locomotives were built at these works, of which 173 were for export.

The plant of these works has been extended by the installment of a battery of 1,664 horse-power of Babcock & Wilcox boilers, automatically fired and tested for 250 pounds steam pressure. The wheel shop has been rebuilt, and electric motors and a traveling crane have been introduced there, and three large electric cranes have been added in the foundry department. A laboratory has been installed for the use of the testing department, and designs for further improvements have been perfected. These are merely awaiting the improvement in business which will justify their inauguration.

The works of the William Cramp & Sons' Ship and Engine Building Company, which now embrace the old Port Richmond iron works of the I. P. Morris Co., with which our honored members, Messrs. Washington Jones and Henry J. Hartley, are identified, have, during the year, turned out two United States cruisers, the "Columbia" and the "Minneapolis," which, on their trial trips, developed the fastest cruiser speeds ever attained, the "Minneapolis," on June 5th, having made 23¾ knots.

These works have also turned out two twin-screw ships for the International Navigation Company, the "St. Louis" and the "St. Paul," each of 11,000 tons, and equipped with two quadruple expansion, tandem engines of 21,000 horse-power. The

"St. Louis" was launched November 12th, and is now nearly completed. The boilers of these vessels have shells of steel $1\frac{9}{16}$ inches thick, with $1\frac{1}{2}$-inch steel rivets. They are subjected to a hydrostatic test of 400 pounds and will be under a constant working pressure of 200 pounds per square inch.

Here, too, have been constructed the turbines for the great works of the Niagara Construction Company.

The I. P. Morris Company's branch of these works has constructed a pump of the Leavitt type for the water-works at Louisville, Ky. The pump was designed by Mr. C. Hermany, Chief Engineer of the Louisville Water Works, and Mr. E. E. Leavitt, of Cambridgeport, Mass.

In closing their report of this pump, Mr. F. W. Dean, expert for the Louisville Water Company, and Mr. Dexter Brackett, expert for the I. P. Morris Company, say :

"The duties, steam consumption, mechanical and thermodynamic efficiencies of pumping engine No. 3, as given in the preceding pages, are remarkable in establishing this as the most economical compound or double expansion steam or pumping engine that has ever been tested, so far as we are aware. It is furthermore remarkable in its mechanical efficiency, as shown by the small friction of the machinery, and this contributes considerably to the duty.

"It is with great satisfaction that we are able to make this statement without qualification, and to further state that the whole plant is a great credit to the designers and builder."

One of the oldest and best known of Philadelphia's workshops is that of Morris, Tasker & Co. While their city establishment, the Pascal Iron Works, has been idle during the year, that at New Castle, Delaware, has been busy, principally in the manufacture of trolley poles, of which from forty to fifty thousand have been manufactured. The firm is now engaged upon an order for such poles for Bristol, England.

The Whitney Car Wheel Works, at Seventeenth and Callowhill Streets, have turned out from 500 to 1000 tons of car wheels per month, besides a large amount of miscellaneous castings.

By a close application of the usual ultimate chemical analyses of pig irons, and by a particular method of construing these

analyses, first discovered and used at these works by Mr. A. W. Whitney, and practically applied during the past three years after several previous years of experimental study, they are enabled to dispense entirely with physical tests of the component irons of their mixtures, while they can predict at the same time with much greater certainty than by such tests, and through a much wider range of physical properties, the character of their castings. They apply the physical tests to the product, only in order to keep track of slight changes. This applies to five regular mixtures at present, two for car wheels and three for softer castings, as they make special mixtures with success on this basis.

The point which may interest engineers is the possibility of having special kinds of cast iron, from stove iron to gun metal, or the whole range of cupola castings, made at one establishment and at short notice.

Equally celebrated, perhaps, with any of those already mentioned, are the works of William Sellers & Co., with which so many of our members have been and still are connected. These works have, during the year, enjoyed a very considerable degree of activity.

In the department of cranes, probably the most notable event at these works was the putting in service of two large cranes for the armor department of the Carnegie Steel Company, at Homestead. One of these was a ladle crane of sixty gross tons capacity, with a fifteen ton auxiliary hoist for tilting the ladle. The other had two trolleys of seventy-five gross tons capacity each. These cranes are operated by series motors of the Westinghouse car type, and the series multiple system of controlling was applied, it is said, for the first time in crane practice. This is the system now generally adopted for car controlling. By it the two motors are used in series or in parallel, the results being better control and smaller volume of current for starting. The general tendency, in crane work, has been toward the use of electric motors for motive power. These are appplied in two ways, either a constant speed motor, driving through a clutch system with mechanical transmission to the various parts, is used, or a separate motor for each of the various movements which it is desired to produce. The Sellers Works

have, during the past year, built traveling cranes operated in each way, and have also applied the electric motor to various swing cranes.

In the department of Testing Machines, these works have continued to develop the emery hydraulic machine, simplifying the construction of its parts and increasing the convenience and efficiency of the system. Among installations made during 1894, may be mentioned the 30,000 pounds traction dynamometer, for the Purdue University, to be used in connection with their well-known locomotive testing machine, by which the pull or tractive force of a locomotive can be determined absolutely under variations of load and of service.

The Sibley College, at Cornell University, has been furnished with a 200,000 pounds horizontal testing machine, complete, with hydraulic scale and pumps; and a 100,000 pounds testing machine, for the Worcester Polytechnic Institute of Worcester, Mass., is now under construction.

In machine tools, the largest single production of the Sellers Works was a lathe of 122 inches swing, 42 feet bed, to take 30 feet between centers. This lathe is simple in design and very massive in construction. It is so arranged that the longitudinal movement of the carriage, the cross movement of the lower slide, and the angular movement of the top slide, which is a new and convenient feature, are operated by quick power traverse, in addition to power feeds. There are three bearings or ways on the bed, the saddle being carried upon two of them, and so arranged that it will run past the poppet head and the steady rest when required. They have also built an interesting multiple punching machine, with an automatic spacing carriage, arranged for punching, in flanges and web, angles, Z-bars and beams, up to 24 inches, and for punching web plates up to 30 inches wide. The punching head is provided with ten punches, adjustable between centers to a minimum distance of 3 inches, and provided with independent gag blocks, so that they may be thrown into service as required. The spacing table, 40 feet long, is arranged for automatic spacing by multiples of $\frac{1}{4}$ inch, with fractional attachment for smaller increments down to $\frac{1}{1000}$ inch.

The Southwark Foundry and Machine Works, by dint of low

prices, have kept their establishment busy with a full force during the year. They have constructed two water-works pumps, several centrifugal pumps for dry docks and sewage, several blowing engines for blast furnaces and Bessemer works, and many Porter-Allen engines, simple, compound and triple expansion, vertical and horizontal.

Among the more important items of work turned out by this establishment are:

(1) Eight vertical, triple-expansion Porter-Allen engines, now working at the Harrison Street Station of the Chicago Edison Company. The regulation, under loads of from 0 to full, is within $1\frac{1}{2}$ per cent., showing virtually a straight line on a Moscrop recorder card.

(2) A pair of vertical, disconnected, compound blowing-engines, which have been working successfully since March 1st at the Edgar Thomson Steel Works, so successfully, in fact, that two additional pairs have been ordered. In these engines, the low-pressure system is entirely distinct from the high-pressure. An automatic governor on the high-pressure cylinder keeps the two at precisely the same speed.

(3) Five horizontal, tandem, compound Porter-Allen engines at the Delaware Avenue power-house of the Electric Traction Company.

(4) Two disappearing gun-carriages, for 8-inch and 10-inch breech-loading rifles, respectively.

As is well known, the site of the venerable Bush Hill Iron Works, which were for so many years conducted by the firm of Matthews & Moore and afterwards by Mr. James Moore, has been acquired by the United States Government for the erection of new buildings for the Philadelphia Mint, but the plant has been purchased by the Philadelphia Roll and Machine Works, which has acquired the ground and works extending from Twenty-third to Twenty-fourth Streets and from Washington Avenue to Carpenter Street, where it will continue the manufacture of rolls and rolling-mill machinery.

These works have long made a specialty of such manufacture. The foundry is being supplied by electric traveling cranes and with air furnaces of the latest design for the production of heavy

castings. The foundry for the production of large roll castings will be in operation by the 1st of March, when sand or chilled rolls and castings up to 30 tons weight can be produced.

Our fellow-member and late Director, Mr. David Townsend, who was associated with Mr. Moore for eighteen years, assumes the management of the new establishment.

Mr. A. Falkenau, whose invaluable services upon the Information Committee of the Board of Directors have already been mentioned, has, during the year, constructed a number of 8-inch shells for the Zolinski pneumatic gun. These shells are 6 feet 8 inches long, and weigh 325 pounds each. Each is composed of eleven principal and 120 minor parts, and the common center of gravity is $33\frac{3}{4}$ inches from the point. The greatest variation allowed is $\frac{1}{16}$ inch in this distance, and $\frac{3}{4}$ of one per cent. in the weight. The shells were very satisfactorily tested at Sandy Hook last summer. A target was placed at sea, 3000 yards out, and eight shots were fired, all of which struck within an area of less than 30 feet square.

Messrs. L. Schutte & Co. have completed, at Twelfth and Thompson Streets, a shop which may be taken as a model for similar establishments, the arrangements being exceptionally complete. In the brass foundry an independent chimney has been provided for each furnace, and the floor construction has been so designed that the shrinkage of the wood does not change the relative level of joists and beams. Large and heavy plate-glass in the windows take the place of the small panes of common glass ordinarily used, and the fire-escape installed has won the special approval of the Board of Fire Underwriters. Mr. L. Schutte, the senior partner of the firm, is an honored member of our Club.

Philadelphia and its immediate vicinity are signally blest in the matter of establishments for the erection of large bridges, and among these, the Pencoyd, Phœnix and Edge Moor Works may properly be regarded as home establishments, although each of them, as a matter of fact, is located beyond the city limits.

The Pencoyd Works of Messrs. A. & P. Roberts & Co., which form the principal field of activity of our honored ex-President and very active member, Mr. James Christie, have lately secured

the contract for the iron-work of the Long Island Bridge, which is to carry the Long Island Railroad across Blackwell's Island and the East River to a new station to be located between Second and Third Avenues and Sixty-fourth and Sixty-fifth Streets, in New York.

The bridge will be a four-track structure and so designed that highways may be added if desired. There will be two river spans of 846 feet each, and a span of 613 feet over the island; and the New York and Long Island approaches will be 2,000 and 5,000 feet long respectively, making a total length of 9,690 feet. The total weight of steel will be 40,000 tons, and the end posts of the long spans will weigh 120 tons each, and measure 4 feet by 6 feet in their exterior dimensions. Pins will be used as large as 18 inches in diameter. The dimensions of these parts are unprecedented except at the Forth bridge.

At these works, also, a new mill for the manufacture of steel beams has been erected, but has not been put in operation. It will contain one pair of 28-inch two-high reversing roughing rolls and two sets of 23-inch three-high finishing rolls. The roughing and the finishing rolls will be separately driven, each by a pair of high-speed engines geared to the mills and connected at an angle of 90 degrees. No fly-wheel will be used in either case.

Both mills are served by mechanical roller tables operated by combined hydraulic and electric transmission, and will be capable of readily and rapidly handling rolled sections 100 feet long. Steel castings are largely used in the construction. A 40-ton electric traveling crane, covering both the mills and their engines, will lift rolls and housings, etc., together, and replace them with another set ready for work.

The material will be heated in regenerative furnaces served by traveling machines operated by electricity.

The Phœnix Iron Company, which, like the Pencoyd Works, has its office within the city limits, has, during the year, furnished the steel framework for a number of prominent Philadelphia buildings, including the William Mann Building, northeast corner of Fifth and Commerce Streets; the Ketterlinus Building, Fourth Street above Arch; the German *Demokrat* Building, Sixth and Chestnut Streets; the Watkins Building, 1031 Chestnut Street;

the Harrison Building, Tenth and Market Streets; the Edison Electric Light Company's Building, Sansom Street above Ninth; and the power-house of the People's Traction Company, Delaware Avenue above Green Street.

This establishment has also constructed shops for William Wharton, Jr. & Co., at Twenty-fifth Street and Washington Avenue, and a storehouse, etc., for the F. A. Poth Brewing Company, Thirty-first and Jefferson Streets.

The Edge Moor Works, besides furnishing the superstructure of the Falls Bridge, have supplied the structural steel work for the Bourse Building and for the Harrison Building, at Tenth and Filbert Streets, and are now erecting the Fidelity Mutual Life Association Building, on Broad Street above Arch, and the Harrison Building, at Fifteenth and Market Streets.

Messrs. R. D. Wood & Co.'s establishment, the Camden Iron Works, to which our director, Mr. Charles L. Prince, devotes so much of his energies as is not monopolized by our Club, has been establishing an experimental plant for firing boilers with gas from the W. J. Taylor producer. Notwithstanding that the boilers are arranged for direct firing (the conduits, etc., not being properly arranged for the purpose), that the boilers are of the ordinary outside-fired tubular type, and that the coal used was a poor anthracite buckwheat with about 25 per cent. of ash, an economy of fuel and an increase of horse-power amounting to from 25 to 50 per cent. have been attained by the use of the producer gas, together with an increase in the uniformity of heat and of steam making. The tubes are not clogged, and an important economy in the handling of fuel and ashes is secured.

Our member, Mr. Max Livingston, reports that the Point Breeze Works of the Atlantic Refining Company have, during the year, increased their capacity by 25 per cent. A new Corliss pump, of 20,000,000 gallons capacity, has been installed to furnish the water used in cooling and washing. The works now cover an area of 200 acres, and the steam plant employed has an aggregate of 12,000 horse-power. The hands employed number three thousand men, and from two to three hundred foreigners of the most heterogeneous nationalities can generally be found at the company's docks.

During 1894, the works loaded 425 vessels, which carried away nearly 325,000,000 gallons (over 963,000 tons) of petroleum products. Two pipe lines bring crude oil from Pennsylvania and West Virginia, delivering 1,200,000 gallons every twenty-four hours.

For packing purposes the works turn out daily from 4000 to 5000 barrels, 50,000 five-gallon cans, and 25,000 boxes.

The Link-Belt Engineering Company has introduced machinery of original design, with link-belt driving apparatus, for handling coal and ashes at the power-houses of the Philadelphia Traction Company, at Thirteenth and Mt. Vernon Streets and Thirty-third and Market Streets; of the Electric Traction Company, on Delaware Avenue, and of the Hestonville, Mantua and Fairmount Company, at Twenty-fourth and Callowhill Streets. The latter includes a dock-leg elevator for the continuous discharge of coal from boats, which is believed to be the first of its kind on the Schuylkill River.

Automatic barrel conveying and elevating machinery has been installed by this company at the works of the W. J. McCahan Sugar Refining Company, where the barrels are automatically delivered to a conveyor, 67 feet long, which transfers them to an elevator 68 feet high. This, in turn, delivers them upon any desired floor.

The company has also equipped three coaling stations for the New York and Hudson River Railroad, at Croton, East Albany, and Lyons, N. Y.

The Dodge Coal Storage Company, which is closely allied with the Link-Belt Engineering Company, has erected a storage plant for the Lehigh Coal Company, at West Superior, Wisconsin. This plant has a capacity of 100,000 tons of anthracite under cover, and 40,000 tons of bituminous coal. The anthracite is in two separate, circular, steel buildings, 246 feet in diameter and 100 feet high, with roofs of parabolic section. The company is also erecting, for the Philadelphia and Reading Railroad Company, at Port Richmond, Philadelphia, a storage plant, with a capacity of 180,000 tons.

Miscellaneous.

Messrs. Wilson, Bros. & Co., of this city, besides their connection with the Reading Subway, for which Mr. John A. Wilson is

consulting engineer, have been active during the year in the design and erection of important buildings, including the completion of the extension of the Academy of Natural Sciences, at a cost of $100,000, the fireproof building of the Women's Hospital on North College Avenue, and the Home for Aged Persons, at Bala.

They have erected, for the University of Vermont, at Burlington, an applied science building and a dormitory, costing $150,000 and $100,000, respectively, and at Indianapolis a training-school, at a cost of $160,000.

Our fellow-member, Mr. Edwin F. Smith, superintendent of the Reading Terminal, estimates the capacity of the ice machines now in use in Philadelphia, at about 500 tons daily, and states that the output of artificial ice, during 1894, was about 70,000 tons, while the consumption of natural ice from the Kennebec, Upper Lehigh, etc., was about 350,000 tons.

The De La Vergne Refrigerating Machine Company, which is represented in this city by our fellow-member Mr. Theodor Kolischer, has been active in the installation of ice and refrigerating machines for the numerous breweries of which Philadelphia boasts, including refrigerating machines for C. Schmidt, Adolph Segal, L. Bergdoll Brewing Co., Continental Brewing Co., Bergner & Engel Brewing Co., and J. P. Baltz Brewing Co.

Messrs. Henry G. Morris and Pedro G. Salom, members of the Club, have constructed an electric wagon weighing 4,250 pounds and equipped with sixty accumulators of 100 ampere-hours each. It has a three horse-power motor, and can develop nine horse-power. The maximum speed attained was three miles in twelve minutes, or fifteen miles per hour, and the longest run made was seventeen miles. The cost of operating and running, say fifty miles per day, is considerably less than with horses. The wagon was purposely made excessively heavy in order to adapt it to the rough usage involved in traveling over our still unreconstructed pavements.

These gentlemen have also erected, at the University Club, the first isolated installation of a combination of the Priestman Oil Engine with storage batteries for electric lighting. These have been operated very successfully.

The Western Union Telegraph Company has put down an underground cable with eighty-two conductors, extending from

Tenth and Chestnut Streets to the Delaware and Schuylkill Rivers. It has recently replaced with dynamos the greater portion of its gravity batteries, and the balance of these at the main office will be similarly replaced. The batteries here previously amounted to 7,000 cells. Copper has generally been substituted for iron wires, and notable improvements in the service have resulted from these changes.

Camden.

Glancing now, for a moment, across the river into our neighboring State, we may note that Mr. L. E. Farnham, the City Engineer of Camden, who favored us with his presence at one of our recent meetings, has lately been studying the matter of a new water supply for that city.

The question was referred to Mr. J. T. Fanning, whose work on Water-Works' Engineering is so widely known. The present pumping station is located at Pavonia, and contains two pumps of 5,000,000 and 10,000,000 gallons respectively, drawing from a basin formed by the Government dike. Mr. Fanning recommends the erection of a new pumping station at Fisher's Point, with increased pumping capacity, and the erection of a settling basin, at a total cost of $645,000.

The population of our neighboring city increased from 9,500 in 1850, to 58,000 in 1890.

Like ourselves, Camden has been exercised over the question of the cremation of garbage, and $10,000 have been appropriated for the building of a crematory; the city being evidently disposed to take this matter into its own hands instead of entrusting it to contractors as is done here.

A very enjoyable feature of the Convention of the American Institute of Electrical Engineers, was a trip over the trolley road equipped by our fellow-member, Mr. J. J. de Kinder, and extending from Camden to Woodbury.

Returning now from this brief excursion into foreign parts, it remains for me only to congratulate you once more upon the prosperity of the Club, and to thank you for the cordial support which you have extended to me during my occupancy of the presidential office, by no means forgetting the patience with which you have followed me through the discharge of this final function.

II.

THE UNITED STATES GEOLOGICAL SURVEY AND ITS METHODS OF WORK.

By Hon. Charles D. Walcott, Director U. S. Geological Survey.

Read, January 5, 1895.

Mr. President and Gentlemen:—Many of you are aware of the origin and development of the United States Geological Survey and familiar with the history of geology in America; but there may be others who are not conversant with this history, and for their enlightenment I shall briefly mention the facts before taking up the main subject of the evening.

At the close of the last century the science of geology was developing rapidly in England, France and Germany. As the tide of immigration crossed the Atlantic it brought with it the existing knowledge and the literature of the subject, and soon thoughtful men, imbued with the spirit of research, began to investigate the geology of the New World. Among the first was William Maclure, who published, in 1809, the results of his observations along the line of the Appalachians, from New York southward. Following him came Amos Eaton and Chester Dewey, who began field work prior to 1820 in the valley of the Hudson. The Geological Survey of Virginia was inaugurated in 1835, under William B. Rodgers, and a reconnaissance was made, followed by more detailed work in the succeeding years. The teaching of Eaton had aroused an interest in the subject of geology in New York State, and the State Survey was organized in 1836, its staff including Timothy A. Conrad, James Hall, William W. Mather, Ebenezer Emmons and Lardner Vanuxem, all of whom published volumes now classical in American geology. Soon after came Henry D. Rogers, whose monumental work, as seen in the reports of the First Geological Survey of Pennsylvania, is perhaps known to you all. Surveys were inaugurated in other States, and the impulse that had its origin in Virginia, New York and Pennsylvania, gradually extended westward.

The discovery of gold on the Pacific coast led to the crossing

of the continent by exploring expeditions, which were usually accompanied by geologists; but it was not until after the close of the Civil War that systematic geologic investigation was begun in the "far West." The Hayden Survey of the Missouri River region and adjacent territory (1867); the King Survey along the line of the Union Pacific Railway west of the 100th meridian (1867); the Powell Survey of the Rocky Mountain region (1870), and the Wheeler Survey of portions of Arizona, New Mexico and Nevada (1869), were inaugurated. By an act of Congress, in 1879, all except the King Survey, which had been terminated by limitation, were consolidated to form the present United States Geological Survey.

Clarence King was appointed Director of the new survey. He began work in Colorado and Nevada, with the intention of confining operations to those States that contained public lands, pending a decision by Congress as to the meaning of the phrase "national domain," which was used in the organic act. This provides that "The Director of the Geological Survey shall have the direction of the Geological Survey and the classification of the public lands, and examination of the geological structure, mineral resources and products of the national domain." Mr. King organized the surveys of the Leadville District of Colorado and the Eureka and Virginia districts of Nevada, and planned for an extended examination of the mineral resources of the country. In 1881 he resigned the Directorship, and was succeeded by Major J. W. Powell.

In 1882 authority was granted by Congress to complete a geological map of the United States. The policy of the survey was then modified, and its attention was directed, under a very comprehensive plan, to the preparation of a geologic map of the country, which included the making of a topographic map as its basis. Topographic and geologic work was begun in the Appalachian region and in various localities in the interior and the far West. The areal geologic work was not rapidly advanced at first, as areal geology, without a good topographic base, would be impossible of accurate representation and of little more value than a reconnaissance. Moreover, the wide domain of the United States presented certain broad and comprehensive

geologic problems, which had to be solved before the areal geologic mapping could be carried forward intelligently and with due regard for scientific accuracy and economy, and to these general problems special attention was at first devoted. With the completion of topographic sheets from time to time, areal geologic mapping was gradually taken up, and in 1894 more than three-fourths of the available geologic force were employed in areal work.

The scope of the work of the survey has now come to include the preparation of a topographic base map of the entire United States; the study and mapping of the areal geology upon this base; the examination of the geologic structure and mineral resources of the national domain; the gathering of statistics of mineral production; and the study of the artesian and surface-water supply of the United States, including, indirectly, the mineral and agricultural classification of the public lands under survey.

There is one fact that should be borne in mind when considering the scope of its work, and that is that the Geological Survey is a bureau of research. Its function is, to a large extent, the discovery of unknown facts and principles and the scientific co-ordination of these and all previously known facts and inductions that fall within the scope of its work, in such form that they shall be useful alike to government and people; the latter term including not only the farmer, the prospector, the miner, the landowner, the investor and the mining and civil engineer, but also the more highly trained student and teacher.

[The speaker here had thrown on the screen a large map showing the areas the topographic work of which had been completed.]

The blue color of the map which I have had thrown on the screen represents the 27,000 square miles of work completed the present fiscal year, and the pink represents the area completed in previous years, which amounts to over 600,000 square miles.

Captain Geo. M. Wheeler said of topographic surveys: "The topographic is the indispensable, all-important survey, being general and not special in its character, which underlies every other, including also the graphic basis of the economic and

scientific examination of the country. This has been the main or principal general survey in all civilized countries, and all other so-called surveys (as geodetic, trigonometric, etc.) are but accessories or addenda thereto . . . the results of such a survey become the mother source whence all other physical examinations may draw their graphic sustenance."

The Geological Survey recognizes, like Captain Wheeler, the importance of the topographic map, and I will now endeavor to explain to you the method pursued in making the topographic map of the United States.

After the base-line is measured, a theodolite (such as that shown on the screen), having an 8-inch circle, is used in all primary triangulation. The field party usually embraces a chief and an assistant, with the addition of a driver and cook, should the party be living in camp.

The next view represents a plane-table, an instrument universally used in map-making. This instrument is applicable to all kinds of country, to all methods of work and to all scales. With it it is possible to make directly from the country a map which can be at once used by the engraver as copy, rendering unnecessary the making of elaborate notes, sketches, photographs, etc., which is not only a more expensive procedure, but one productive of inferior results. The plane-table is very simple in construction, consisting of a board upon which is fastened a sheet of drawing paper. The board, as shown in the view, is mounted upon a tripod. It is capable of being leveled, of being turned in azimuth, and of being clamped in any position. Upon the paper is produced directly, in miniature, a representation of the country. Directions are not read off in degrees and minutes, but are plotted directly upon the paper. The instrument used for this purpose is the alidade, the principal part of which you see rising above the board. Its base is a ruler with a beveled edge, to which is attached a telescope that turns on a horizontal axis. This telescope carries also a delicate level and a vertical arc for the measurement of angles in the vertical plane, from which relative heights are obtained. A full description of the plane-table used by the Survey and of the method of using the same may be found in a volume entitled "A Manual of Topographic

Methods," which constitutes Monograph XXII of the Geological Survey.

We now have before us, on the screen, a view of the traverse plane-table and ruler alidade, which is used for traverse work. In this work the wheel is used for measuring distances, and the direction is obtained by the traverse plane-table.

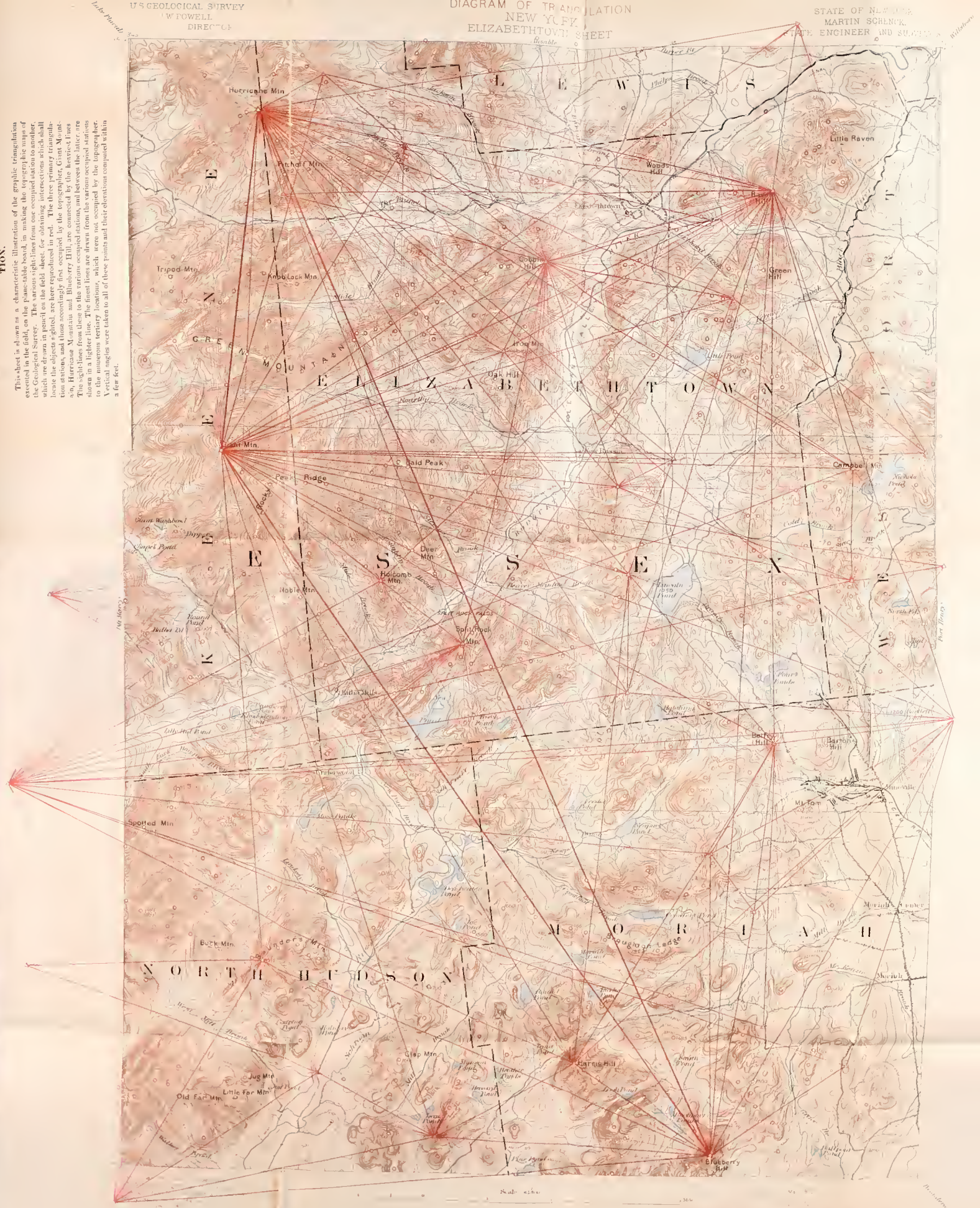
There will now be thrown upon the screen several views illustrative of the methods of transporting instruments and supplies by pack-train and wagon; the surveyor's most constant friend in Western work, the mule, being shown under various conditions, as well as the topographer at work and in camp.

The first illustration of triangulation is that of an area covering several thousand square miles in central Texas. This was extended from a base-line near Austin, on the south, and another near Fort Worth, on the north. From these two lines triangulation was carried forward, northward, southward and westward, and joined about half way between the two base lines. The next view illustrates the triangulation, so far as it has advanced, in New York, Pennsylvania and New Jersey. This comprises the work of the Coast and Geodetic Survey, the Lake and River Survey, the Gardner Survey of New York State and the U. S. Geological Survey. In all the work of the Geological Survey, advantage is taken of the triangulation of the Coast and Geodetic Survey and all other reliable surveying organizations. In the Eastern States all the work is based upon such triangulation. In Kansas and many other States of the West, we have been able to use the Land Office surveys for the secondary control, the primary triangulation first controlling the Land Office work. This is well illustrated by the view now upon the screen.

We will now look at a few topographic sheets which show the more detailed triangulation and intersection lines by which the topography of the atlas of the United States is controlled. The first is the Albany sheet of New York. The points of primary triangulation are situated on the hills east of the Hudson and at several places on the Helderberg Mountains. The secondary triangulation is made from these primary points, and, as you see, it makes a complete network over the sheet. In the still more rugged country to the north, in the vicinity of Rutland, Vt.,

ELIZABETHTOWN SHEET. DIAGRAM OF TRIANGULATION.

This sheet is shown as a characteristic illustration of the graphic triangulation executed in the field, on the plane-table board, in making the topographic maps of the Geological Survey. The various sight-lines from one occupied station to another, which are drawn in pencil on the field sheet, for obtaining intersections which shall locate the objects sighted, are here reproduced in red. The three primary triangulation stations, and those accordingly first occupied by the topographer, Giant Mountain, Hurricane Mountain and Blueberry Hill, are connected by the heaviest lines. The sight-lines from these to the various occupied stations, and between the latter, are shown in a lighter line. The finest lines are drawn from the various occupied stations to the numerous tertiary locations, which were not occupied by the topographer. Vertical angles were taken to all of these points and their elevations computed within a few feet.



where the primary triangulation is from mountain top to mountain top, and the secondary or plane-table triangulation and intersection lines are located on marked topographic features, we have a better illustration. The heavy lines indicate the primary triangulation and the lighter lines the secondary control. The area of the sheet is a little less than 250 square miles.

In the atlas sheet now thrown upon the screen the primary triangulation-lines are omitted; but the points of control are shown—the primary triangulation locations, by small triangles; the other points, by dots enclosed in small circles. This control is also shown for one of the Arkansas sheets. Usually, while the triangulation is progressing the traverse work is being carried forward over the area of the atlas sheet. This is for the purpose of locating roads, streams of importance, and any other linear features that it may be desired to represent. Distances along streams and boundary lines, lake shores, etc., are determined by the stadia method, but distance on the roads is usually determined by counting the revolutions of a wheel, it having been found that with the same degree of care the wheel gives more satisfactory results than the stadia in road measurement. When the traverse work is completed, it is transferred to the sheet upon which the triangulation has been done, and is fitted to that triangulation; thus, there is assembled upon one sheet all the control of the map.

We will now pass on to consider the work which is shown upon the published map. All of the triangulation and points of location are omitted from the final map. The scale upon which the field work is executed is usually larger than that upon which the map is published. In the Northeastern States the field work was set at 1:45,000, the scale of publication being 1:62,500. In most other sections of the country the scale of field work is two inches to the mile where it is to be published upon the mile scale, but one inch to the mile where it is to be published upon the two-mile scale. While engaged in field work, the topographers are required to make a monthly report to the chief of the section and the Chief Topographer, which reports call for statistics concerning the control of the work and its progress. Inspection of the work is done by the chiefs of parties and of

sections, and in special cases by persons detailed by them for the purpose.

With the sheet on the plane-table, a topographer, usually the most experienced one in the party, goes over the ground and sketches the contours, streams and culture, which constitute the map. In doing this he is guided everywhere by located points, sketching the details between these points by the eye. For instance: the junctions of all minor streams, which may not have been traversed, are located, and between those points they are sketched. For the location of contours he has the position and elevation of the summits of all hills, of the shoulders of spurs and of the bottoms of valleys. With these locations and measurements the contours of each hill are sketched from points commanding the best view thereof, the contours being interpolated to suit the measured heights and positions.

The Sandy Hook sheet, now on the screen, is a fine illustration of a type of topography which is found in the lowland region of New Jersey, along the Atlantic coast. The distance between contours is 10 feet. If you start from the shore-line (indicating) and go back toward the low hills, the first contour is 10 feet above mean tide, the next 20 feet, and so on to the summit of the first hill, which is 80 feet above tide. The form of this hill, including its irregularities, is shown by the contours. Other maps to be shown will explain this more clearly. The next view is of the Atlantic shore of the Salem sheet of Massachusetts. Here the contour interval is 20 feet, and the steep and rounded hills are beautifully shown; also Salem harbor and other features of the topography of the region. These two views are introduced to show the relations of the contour lines to the mean level of the ocean. The next view is one of the Mt. Washington sheet. Mt. Washington, in the southeastern part, is 6,290 feet above sea-level. The contour interval is, like that of the Salem sheet, 20 feet, and as we proceed down the mountain side in any direction the contours are seen to be closely crowded together, which indicates the great steepness of the slopes. To the westward, toward Fabyan's, the greater distance between contours indicates a more gradual slope. The great ridges and spurs of the main mountain, with their intervening ravines, are

U. S. GEOLOGICAL SURVEY
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DIRECTOR

DIAGRAM OF CONTROL
NEW YORK
ELIZABETHTOWN SHEET

STATE OF NEW YORK
MARTIN SCHENCK,
STATE ENGINEER AND SURVEYOR

ELIZABETHTOWN SHEET. DIAGRAM OF CONTROL.

This sheet is similar to the former in that it shows all the points located by the graphic plane-table triangulation, but differs from it in being directed of the sights lines showing how these locations were obtained. In addition, there are brought out in red on this sheet all of the roads or trails over which instrumental traverse lines were run; and by little solid dots locations obtained by intersection from this traverse are shown. The result is a complete exposition, in red lines, circles, and triangles, of the amount of instrumental control, on which the sketching is dependent. The horizontal position, and this aids the topographer in sketching the contours of the higher relief. Elevations obtained along all of the traverse lines, in addition to their horizontal location, afford the topographer mathematical control and data on which to base his sketching of the valley bottoms and the lower relief.

beautifully shown by the curvature of the contours. I may add that upon all the final maps the contours are printed in brown, the hydrography—that is, the streams, lakes, etc.—in blue, and the culture—roads, boundary lines, towns, houses, etc.—and the names in black.

The next view is a map of the Harvey Lake district of Pennsylvania. It represents a somewhat different phase of topography, there being a broken system of hills; but the parallel ridges, so characteristic of Pennsylvania, are beautifully shown in the next view, which represents the Harrisburg sheet. Here the Susquehanna cuts directly across Blue Mountain and Second, Third, and Peters Mountains, which are all long, narrow ridges, trending northeast and southwest. The city of Harrisburg, the numerous railroad lines and country roads, the bridges crossing the river, and the islands in the river, are all clearly shown; also the rounded hill topography to the north and south of the four parallel ridges already mentioned.

We will now pass in review several sheets. The Charleston sheet of West Virginia represents a dissected plateau, broken into a thousand hills and valleys by the drainage lines. The Estillville sheet touches portions of Kentucky, Virginia and Tennessee, and illustrates a divergence in the usual trend of the Appalachian ridges; in its northeastern portion the irregular mountain mass of Harlan County, Ky., appears. The rugged mountain area of North Carolina is shown by the Mt. Mitchell sheet, now upon the screen. The topography of this area is unlike that of the Blue Ridge region, being more like that shown by the Mt. Washington sheet.

Passing next to the Anthracite sheet, we have a view of the Rocky Mountain topography of Central Colorado. Here Mt. Carbon rises 12,000 feet; the crest of the Anthracite Range, Ohio Peak, is over 12,000 feet high; and there are a large number of prominent points and ridges, with more or less narrow valleys between. There is, however, nothing of the regularity seen in the Appalachian Range as it crosses Pennsylvania.

The next view is of the plain and cliff region as shown by the Lamy sheet of New Mexico. Here the gentle slope of the plains is indicated by widely-separated contours; and the cliff lines

are shown by the crowding together of a large number of contours within a narrow limit of space; the cliffs are thus seen to extend northwesterly across the northeastern portion of the sheet. The cliff just southwest of the Atchison, Topeka and Santa Fé Railroad line must be at least 700 feet high, as there are fourteen or more of the fifty-foot contours crowded together and forming on the screen what appears to be a broad, black, irregular line.

We now see a photograph of one of these cliff lines. You will recall that, on the contour map, the contours of the cliff line were broken by numerous curves, indicating amphitheatres in the cliff, and projecting headlands and points. The next view represents one of the amphitheatres in the sandstone cliffs. I may mention here, what has not been spoken of before, that the purpose of the contour map is to represent the country as viewed from above—a bird's-eye view, in fact—such as would be obtained by looking down from a point a mile or two high; at the same time preserving the record of the relative elevations and depressions of the surface, which are less in the perspective of a bird's-eye view from above. Thus the photograph that we have just seen shows the elevation of the cliffs from a horizontal view, whereas the topographic map shows the distribution of the cliffs and the various elevations and depressions over the surface, the contours indicating the relief seen in the horizontal view.

We will now glance at the Sun Prairie sheet of Wisconsin, which illustrates beautifully the drumlins formed during the glaciation of the northern portion of the United States. The elongated, rounded hills all trend in the direction that corresponds with the general movement of the glacier in this region—northeast-southwest. This system of hills may be compared with the sand-hills of the Dunnellon sheet of Florida. The difference in the topography of these two localities, and in the mode of its origin, is shown very clearly.

Another Southern sheet, the Thibodeaux sheet of Louisiana, illustrates a quite different phase of topography. You will observe that the contours, which here have 5 feet difference of elevation, extend from the Mississippi River a short distance southward, and that the total elevation is 15 feet, after leaving

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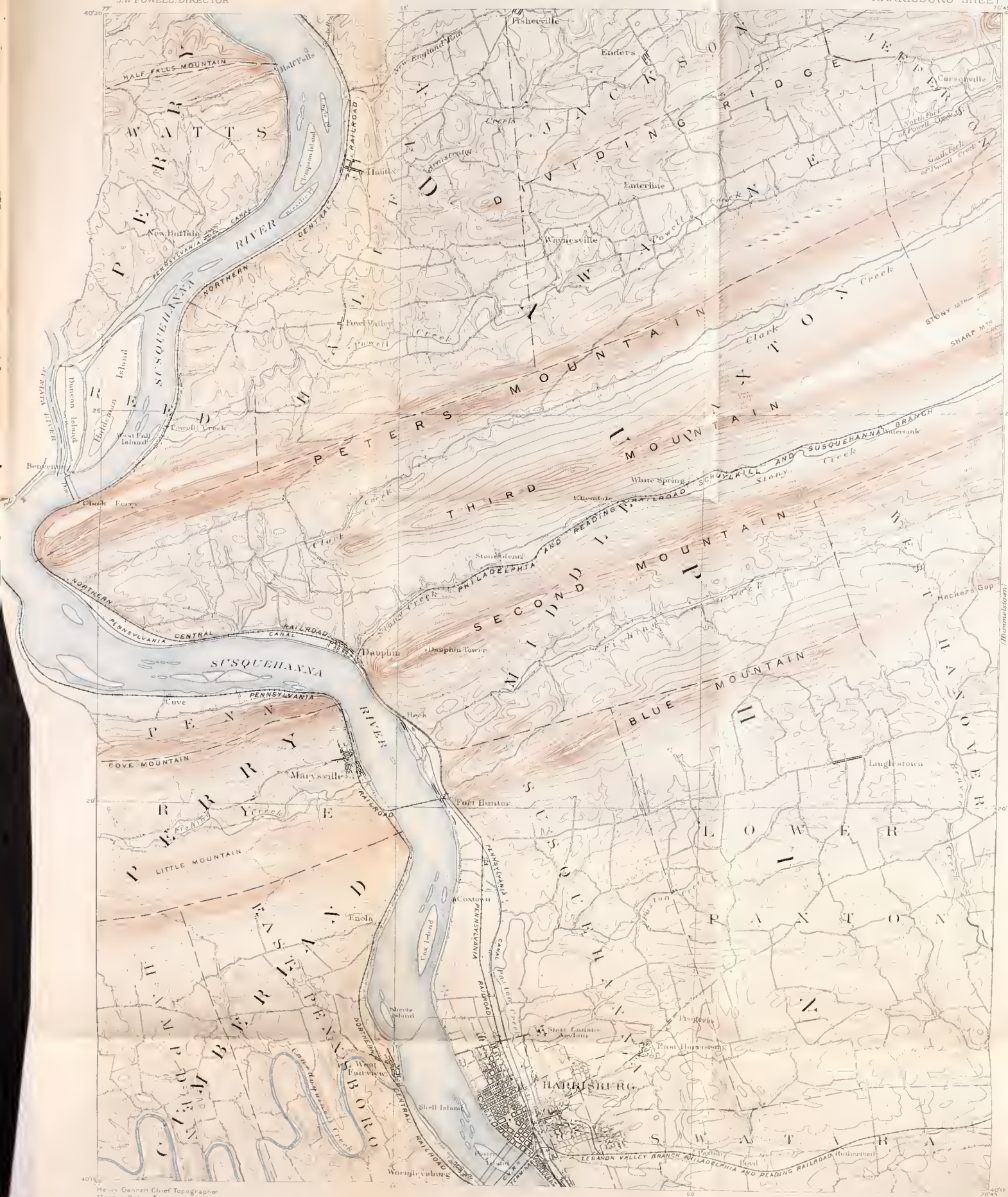
PENNSYLVANIA
HARRISBURG SHEET



Henry Gannett Chief Topographer
Marcus Baker Topographer in charge
Triangulation by U.S. Coast and Geodetic Survey
Topography by the same

Scale 1:62500

Contour Interval 20 feet
Datum is mean Sea level

Edition of Mar 1892

HARRISBURG SHEET.

This atlas sheet is a typical example of thirty-six similar sheets of portions of Pennsylvania published by the Geological Survey. It is shown herewith as an illustration of the several characteristics of the topography of the anthracite coal fields. The contours, the vertical interval between which is twenty feet, bring out graphically the long, parallel finger ridges of this portion of the Appalachian Mountain system. The manner in which the Susquehanna River cuts abruptly through these ridges is characteristic of similar streams in the same region. Along the foot hills of these mountains, especially the northern slope of Little Mountain, in Perry County, are seen some of the peculiar pirate streams, which have cut through and made gorges in the sides of the greater mountain, thus creating lower, secondary parallel ridges. The peculiarly broken up and flat character of the country about Harrisburg is well brought out by this map.

the immediate margin of the river. From the lowest contour southward more than half way across the sheet there is a broad swamp which extends to the slope that reaches down to the Bayou Lafourche. There appears to be a difference in elevation between the ridge near the Mississippi and the bayou of about 5 feet, the slope being toward the bayou.

My object in thus bringing before you this series of sheets is to show you the different phases of topography that the Survey meets with in preparing the topographic atlas, and the clearness with which the topography may be represented by the contour system.

The Geological Survey has completed, as I have already said, over 600,000 square miles of topography. A portion of this is upon the four-mile scale, which is inadequate for the geologic mapping. This leaves about 500,000 square miles available for such mapping. The 100,000 square miles not available for that purpose were surveyed during the earlier history of the Survey, part of the work being in the mountains of West Virginia and Tennessee and part in Colorado and the Rocky Mountains; and a considerable portion of the work of the Irrigation Survey is also inadequate for geology.

The area of the State of Pennsylvania is about 46,000 square miles, of which 6,537 square miles have been surveyed. During the past summer the region immediately about Philadelphia was resurveyed; and within a few months we shall have a new topographic map of your city and vicinity.

The geologic work of the Survey, which will now be briefly discussed, has two phases: (1) special investigations and (2) general or areal mapping.

The special work is illustrated by the monograph on the mining industry of Leadville, Col., by Mr. S. F. Emmons, and by that on the tertiary history of the Grand Canyon District, by Capt. (now Major) C. E. Dutton. Mr. Emmons spent two or three years studying the structural geology of the Leadville region, and working out the mode of occurrence and distribution of the ore-bearing bodies, and he indicated, as far as possible, the lines along which mining development should proceed. The opinion of miners and mine owners is that this work has been of great

assistance in the development of the various mineral deposits about Leadville. The extent of the special work of the Survey is shown by the 24 monographs and 117 bulletins that have been published as the result of such investigations. These special investigations frequently furnish the basis for generalizations that must be made before the areal geologic work can be successfully prosecuted, and the areal geologist is constantly making use of data supplied him by the specialist.

Areal geologic work is now being carried forward in many localities. The present year there were parties mapping the coal fields of Tennessee, Virginia, West Virginia and Maryland, and the iron-ore deposits of western North Carolina. One party was at work on the marbles, etc., of northwestern Georgia; one party made a preliminary study and reconnaissance of the gold belt of Georgia, South Carolina, North Carolina and Virginia; one party defined the southern limit of the roofing-slate belt of eastern New York; one large party worked in the iron-ore districts of northern Wisconsin; one party in the mining districts covered by the Helena sheet of Montana; two parties in Colorado, reviewing the Leadville work and the Cripple Creek gold camp; two in the gold belt of California, and so on; making twenty-eight geologic parties in the field in various portions of the country. In the spring we propose to take up the mapping of the coal field in Washington, and also resume work on and complete, if possible, the mapping of the phosphate areas of Florida.

Let us now proceed to the illustration of the method of areal geologic mapping.

With the topographic base map in hand, the areal geologist proceeds to examine every outcrop of rock in each square mile embraced within the map, noting the strike and dip, and all openings the result of quarrying, mining, building of railroad lines, or the cutting of canyons by streams. He plats on the maps the distribution of formations and the structural features, and takes extensive notes of all matters bearing on the geology. On his return to the office he studies all his data—maps, notes and specimens—with great care, and proceeds with the preparation of a geologic folio, which includes the area embraced in one topographic atlas sheet. The area surveyed in a field season

varies with the character of the geology, being from 250 square miles in a highly complicated region to 3,000 or 4,000 square miles in one of very simple structure.

To illustrate the result of such work we will take up the Chattanooga folio of Tennessee. First, we have on the screen the topographic base map, the construction of which has been explained. Now we see the areal or general geologic sheet. You will observe that the colors illustrating the distribution of the formations are superimposed directly on the topographic map, the contours, streams, boundary lines, roads, etc., of the topographic map showing through the colors. The blue color in the northwestern section, and also the broad band of blue in the central portion, stretching northeastward and southwestward, represent the Carboniferous coal-bearing formation; the pink and purple colors represent the Silurian iron-ore-bearing rocks and the limestones, shales, etc. In order to bring the facts out more clearly for the use of the mining engineer and those interested in mineral development, a second geologic sheet is prepared, upon which the formations carrying economic minerals are indicated by distinct colors. As you will see on the screen, the formation bearing the iron ores is indicated by a bright vermilion, and that bearing coal by a deep blue. These two colors indicate the distribution and extent of the outcrops of coal and iron within the 975 square miles embraced in the Chattanooga sheet. The limestones, shales, etc., are also clearly indicated by their respective tints. Any person taking this sheet into the field may readily learn whether the land he is examining is underlain by coal, by iron, or by limestone. The two geologic maps that have been thrown upon the screen illustrate the surface distribution. In order to impart the information which the geologist has obtained concerning the underground distribution of the rocks which appear at the surface, another sheet, the structure-section sheet, is prepared. If you will look carefully at this sheet as it is presented on the screen, you will see that the iron-ore formation passes beneath the coal-bearing rocks of Walden Ridge and reappears on the opposite side, and that the same formation is faulted down on the eastern side of the Sequatchie Valley, so as not to present any outcrops at the foot

of the steep bluff that rises from the valley to the plateau above. On the eastern side of the sheet are the structural features of the limestone and shales. A glance at the central section will explain why it is that iron is manufactured so cheaply in this region. The coal deposits are in the sandstones on the top of the plateau. The coal is run by gravity railroad to the valley below, where it meets the iron ores that are being mined at the foot of the ridge, the furnaces being located in the vicinity of the iron-ore mine and standing directly on the limestone-bearing formation, which affords an abundant supply of flux. The last sheet is one of columnar sections, in which the vertical relations of all the formations shown in the area are drawn to scale. The folios are accompanied by a text describing the geography, stratigraphy and mineral resources of the region. The inside of the cover bears a general explanation of the topographic and the geologic maps and of their uses.

Another type of the areal geologic work is shown in the Pike's Peak folio of Colorado. This covers a region of eruptive rocks, upon which, here and there, sedimentary deposits have been laid down. This sheet includes the Cripple Creek mining district, and embraces an area of country of 932 square miles, the main portion of which is underlain by the Pike's Peak granite, through which, here and there, subsequent eruptions of phonolite, rhyolite, trachyte, andesite, etc., have forced their way. The main mass of the Cripple Creek eruptive is an andesite breccia, through which dikes and irregular masses of phonolite have broken. Mr. Whitman Cross, who surveyed the district, is inclined to the opinion that this area represents an ancient volcano, the successive eruptions of which deposited the rocks as now found. On the structure sheet, now on the screen, this idea is clearly represented by the central section. It is probable that as the volcanic forces were diminished, hot springs brought up minerals which were deposited in the crevices and dikes formed during the period of eruptive action. These features will be brought out more in detail on a special map now in preparation, the result of a detailed survey made during the past summer by Mr. Cross and Mr. R. A. F. Penrose.

These maps exhibit our methods of work and the mode of final presentation of the areal geology. Up to the present time

eight geologic folios have been published, and there is material on hand for sixty more. These will be published as rapidly as the facilities of the Engraving and Printing Division of the Survey will permit.

Before inviting attention to the subject of economic work, I wish to state that there were sixty field parties out during the past season, twenty-eight engaged in geologic work and thirty-two in topographic surveys.

As members of an engineering club, you are interested in questions of direct economic importance. The illustrations and descriptions that I have given explain, in some measure, the economic bearing of the work of the Survey.

In regard to the mineral resources, the organic law of the Survey provides that the Director shall have charge of the "examination of the mineral resources and products of the national domain." This has been interpreted to mean a statistical examination of the products from the mineral resources, and a geological examination of their occurrence and character. The former has led to the compilation of statistics and the publication of an annual volume, entitled "Mineral Resources." It is proposed to continue this work, and to make it as complete and accurate as the means available will permit. It seems particularly appropriate that the Government should collect statistics of mineral production, and give the volume prompt publication and wide circulation. The first ten annual volumes have appeared as a distinct publication by the Survey; but in future it is proposed to issue the statistics as the second part of the annual report of the Director.

In August last an appropriation was made by Congress for "Gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in arid and semi-arid regions." Under the authority of this statute, river-gauging stations were established in many of the rivers and streams of the West. The instrument used in this work is represented on the screen. It is called the Haskell current meter. The instrument is placed in the stream, and the revolutions of the fluked wheel are recorded on shore by means of an electrical apparatus. It is a simple instrument, but very effective where the flow is of medium veloc-

ity. For very rapid streams there is a modification, consisting of an extra wheel with flatter flukes, which is substituted for the one commonly employed. For very quiet waters another meter, with cup-shaped vanes, is used—one that will record even the slightest movements. All of these gauges are tested and rated at a rating station before being put into actual service.

The sketch now on the screen illustrates the volume and flow of water in the Rio Grande throughout the year. It will be seen that the greater part of the water passes out during the months of March, April and part of May, and goes to waste. If this water could be stored in reservoirs and distributed during the period in which it could be best utilized for the irrigation of growing crops, large areas of desert land would be rendered productive. During the past season I visited the Boise Valley, in Idaho, where valleys that for nine months in the year are as dry as this floor have been dammed and the flood waters held back in winter and successfully used for irrigation during the spring and summer.

We will now glance at the map which Major Powell showed you when he talked to you upon the run-off waters of the United States. In the eastern section of the country the average annual run-off is 20 inches and upward; over the Mississippi section it is from 10 to 20 inches; over the Great Plains, from 2 to 5 inches; and west of the Rocky Mountain region, from 0 to 5 inches, except on the high summits, where it is larger.

Another subject of economic importance is that of the materials to be used in the building of highways. This is distinct from the engineering problem and the mechanical construction of roads—a subject which the Survey does not intend to take up. The main question that the geologist has to do with is the choice and manipulation of materials. Experience has shown that many kinds of rocks that are not suitable for road building when used alone may be combined with other materials in such way as to give excellent results.

The movement for the betterment of roads and for obtaining information relating to materials for the purpose has not yet taken a national character, but it is probable that it will do so and that a laboratory will be established for testing road materials, for the benefit of road commissioners, of geologists

engaged in areal mapping, and of public-spirited citizens interested in the making of good roads. It is also probable that it will be found desirable to test the various clays which may be used in making vitrified paving brick. It now seems likely that such clays will become of great value for brick-making in sections of the South and the lower Mississippi Valley, and it is important that the investigation of the clays of the country with reference both to distribution and burning qualities should be undertaken.

In this connection I wish to call the attention of the Club to criticisms that have been made of what has been termed the purely scientific or technical work of the Survey. Some have urged that all abstract studies should be left to the universities and technical schools. These critics fail to recognize the fact that scientific or technical knowledge is constantly necessary to the solution of geologic problems, and that if such knowledge is wanting, investigations must be made in order to obtain it. Geology is essentially a science of exploitation, and the geologist must have at hand the best instruments and the most reliable information that can be obtained to aid him in observing and in recording observations, in classifying and assimilating the results, and in correctly interpreting them. He must understand the principles and laws that govern the phenomena under investigation, and, if necessary, he must obtain that knowledge by the expenditure of much time and energy.

Another subject of interest to those concerned with the development of scientific geologic work is co-operation with State Surveys. The attitude of the Federal Survey toward State Surveys has been in the past to co-operate fully and freely, though commonly in an informal way; and it has uniformly encouraged the institution of State Surveys. It has been disposed to encourage a division of labor whereby economic problems o a local character would be dealt with chiefly by the State Survey, while the more general and usually inter-State problems, which State Surveys have difficulty in dealing with, would receive the special attention of the Federal Survey; the latter problems, including triangulation, topography, paleontology and special researches, requiring specialists and much time and labor.

Co-operation in topographic mapping has been effected in

Massachusetts, Connecticut, Rhode Island and New York, under an arrangement by which each State pays one-half the cost of the work, the details of scale, etc., being agreed upon by a commission or an officer, representing the State, and the Director of the Federal Survey. It is essential that uniformity of method and results should obtain throughout the topographic maps, and to secure this, the execution of the field work and the drafting and engraving of the maps have been entirely in charge of the Federal Survey. If agreeable to other States, co-operation with them arranged, will be on essentially the same conditions. The legislature of Georgia has just passed a bill authorizing co-operation, and a bill providing for co-operation is pending in the legislatures of Washington and Wisconsin.

Under our appropriation we can, working independently, allot with fairness, say, $5,000 in the State of New York, and therewith map 500 square miles. Under the co-operative agreement that subsisted a year ago that State appropriated for one year's work $25,000, and the United States Geological Survey allotted the same amount, and an area of 5,000 square miles was mapped. If the whole annual appropriation of the Federal Survey were expended within the borders of a single State like New York, it would be possible to map the entire area of that State in one year and a half; but this would be manifestly unjust to the other States, so we distribute the work, except where the States show their interest by entering into co-operation and meeting one-half the cost, in consideration of the more rapid survey of their area.

It is not practicable adequately to summarize in a few paragraphs the results of the work of the Survey for the period of 1879–1894. A fuller statement has been made in the fourteenth and fifteenth annual reports of the Director of the Survey. To recapitulate briefly: Of topographic surveys 624,000 square miles have been completed, of which 500,000 are available for areal geologic mapping; of geologic surveys 100,000 square miles have been completed, of which 60,000 are ready for the engraver; of special geologic and miscellaneous investigations there have been published 15 large annual reports, 117 bulletins and 24 monographs; of mineral statistics 10 annual volumes have been published, and many thousand topographic and special geologic

maps have been printed and distributed; and what is perhaps of most importance, a material and intellectual equipment has been assembled that will have a marked influence in all future work. The legislative branch of the Government has been very liberal in the past; and it is anticipated that the work will be fully sustained in the future. On the part of the Survey, it is proposed to retain the services of the most capable men that can be secured, to maintain the work at the highest standard of efficiency possible, and to advance it as rapidly as the means provided will permit.

Before closing, I wish to have thrown upon the screen a few views illustrating some of the scenic topography of the West. They are principally views of southern Utah and of the great canyon of the Colorado, and they will give you a slight idea of the rugged grandeur of this Wonderland of America.

[The speaker then described the several views thrown upon the screen.]

After some remarks by Messrs. Birkinbine and Dahlgren, Mr. Walcott further stated that he had with him a few copies of the topographic sheets of Pennsylvania, which the members of the Club were at liberty to take with them, if they cared to do so. "I will say further," he added, "that if there are any members of the Club who wish copies of these Pennsylvania sheets, or of the sheets of any portion of the United States that has been mapped by the Survey, I will cheerfully have such sheets sent to them, if they are in stock. When the working edition of any topographic sheet is printed there are usually provided a number of copies for distribution to those who have special use for them." Continuing, he said: "It may be well to state that any one applying for the maps should inform the Director of the use he wishes to make of them, as the supply is much too small for distribution to persons who seek them merely for the gratification of possession or to fill an empty shelf or corner of a library. There is an amendment now pending before Congress providing for either the free distribution or the sale of the topographic sheets, with a simple descriptive text, to public schools and academies and to persons interested in the teaching of physical geography.

III.

INVESTIGATION AND EXPERIMENTS FOR THE DETERMINATION OF THE GROOVE IN GUARD RAILS FOR STREET RAILWAYS.

By V. Angerer, Active Member of the Club.

Read, February 2, 1895.

The object of the investigation herein to be detailed was to find the most desirable shape and proper widths of the groove that should be used in the guard rails for curves of street railways, especially electrical railways, the fundamental idea being that were these grooves laid out as nearly to the lines of wear, thereby presenting from the start the largest possible wearing surface to the action of the wheels, the life of the rail would be prolonged.

Due consideration, of course, had to be given, in arriving at the result, to the economical manufacture of such rails, and an average had to be found to make the use of one rail possible under varying circumstances without losing sight of the object.

I give in full the details of my investigation and the line of thought I have followed, and if, in some parts, I have made my account rather lengthy, it was done with the object of more forcibly presenting every step taken toward the result.

The first question to be determined was the best method to pursue in making the investigation, and how to approach the subject. To do so from a theoretical standpoint involves very laborious and tedious work, with doubtful results. In a car traversing a curve the longitudinal axis of the car or truck should take the position of a normal to the radius of the curve; the wheels and axles being rigidly connected with the car, the plane of the former will remain parallel with this normal, and the center lines of the axles will be parallel with the radial line drawn to the center of the car or truck. This position is indicated in Fig. 1. Of the wheel, the tread part rests on the head of the rail, while part of the flange projects down into the groove, and this is the only part of the wheel which has to be taken in

consideration in the determination of the shape and size of the groove in the rail, that is only the part of the flange lying below

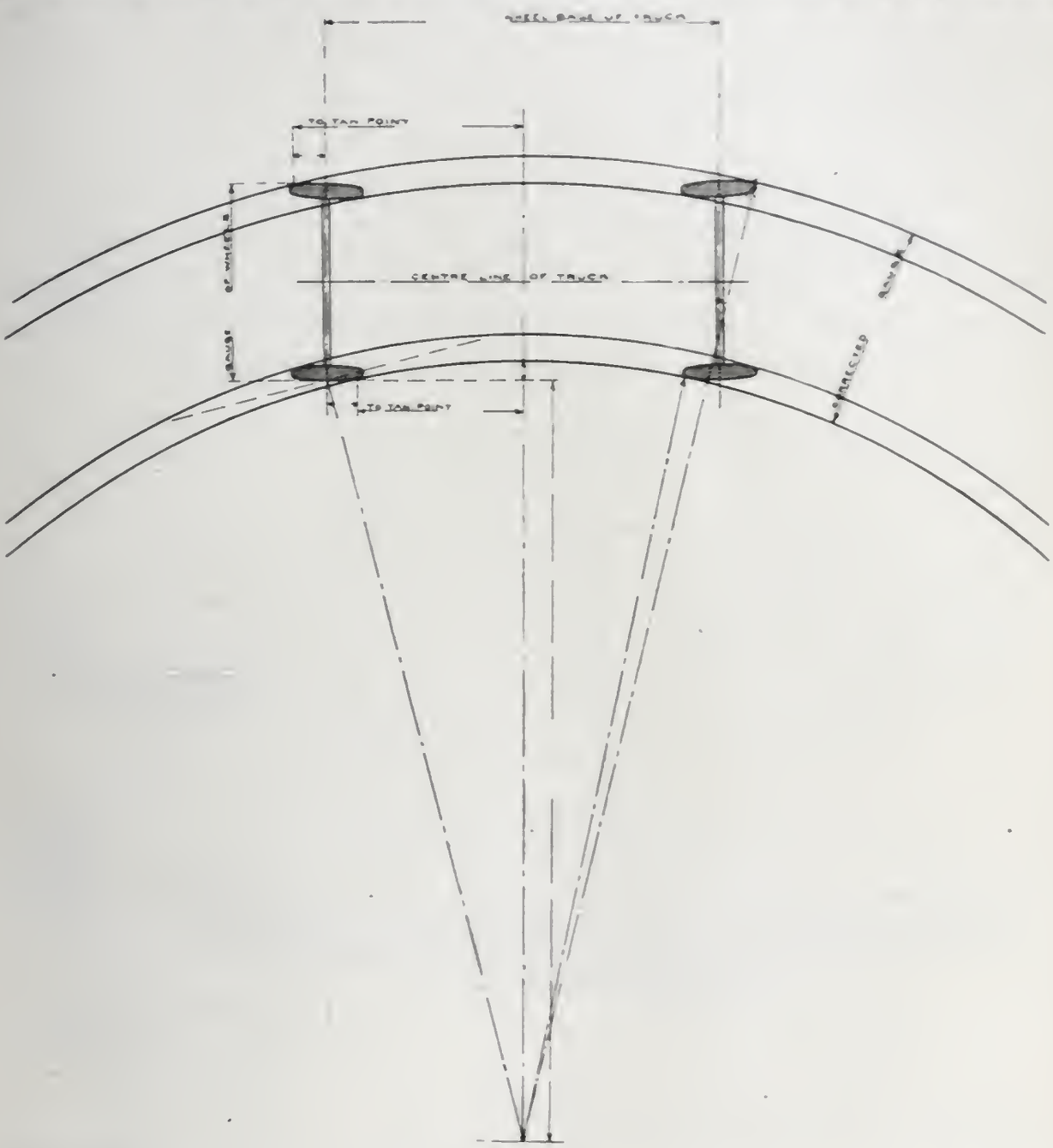


FIG. 1.

the line A. B. (Fig. 2.) Taking a section at the line A. B., we find an oblong contour, the exact lines of which depend on the

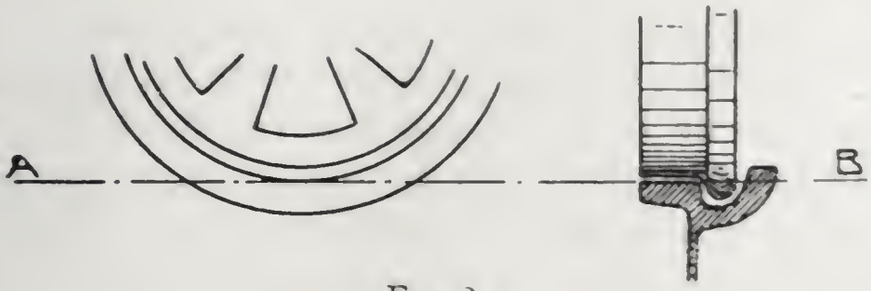


FIG. 2.

size, that is, width and depth, and shape of the flange, and the diameter of the wheel. The diagram below shows such a section taken on a wheel of 33″ diameter, with a standard flange $\frac{3}{4}''$ deep and $\frac{7}{8}''$ wide. In Fig. 1 these sections of the four wheels are shown in their relative positions to each other, to the car or truck-body, and to the curve. It will be readily seen that circles drawn from the center of the curve, tangent to the periphery or contour of these sections on both sides will represent the limits of the groove; that is, the distance between the two circles tangent to each section is the width of the groove on a level with the tread or head of the rail, the wheel itself setting on an angle partly across the

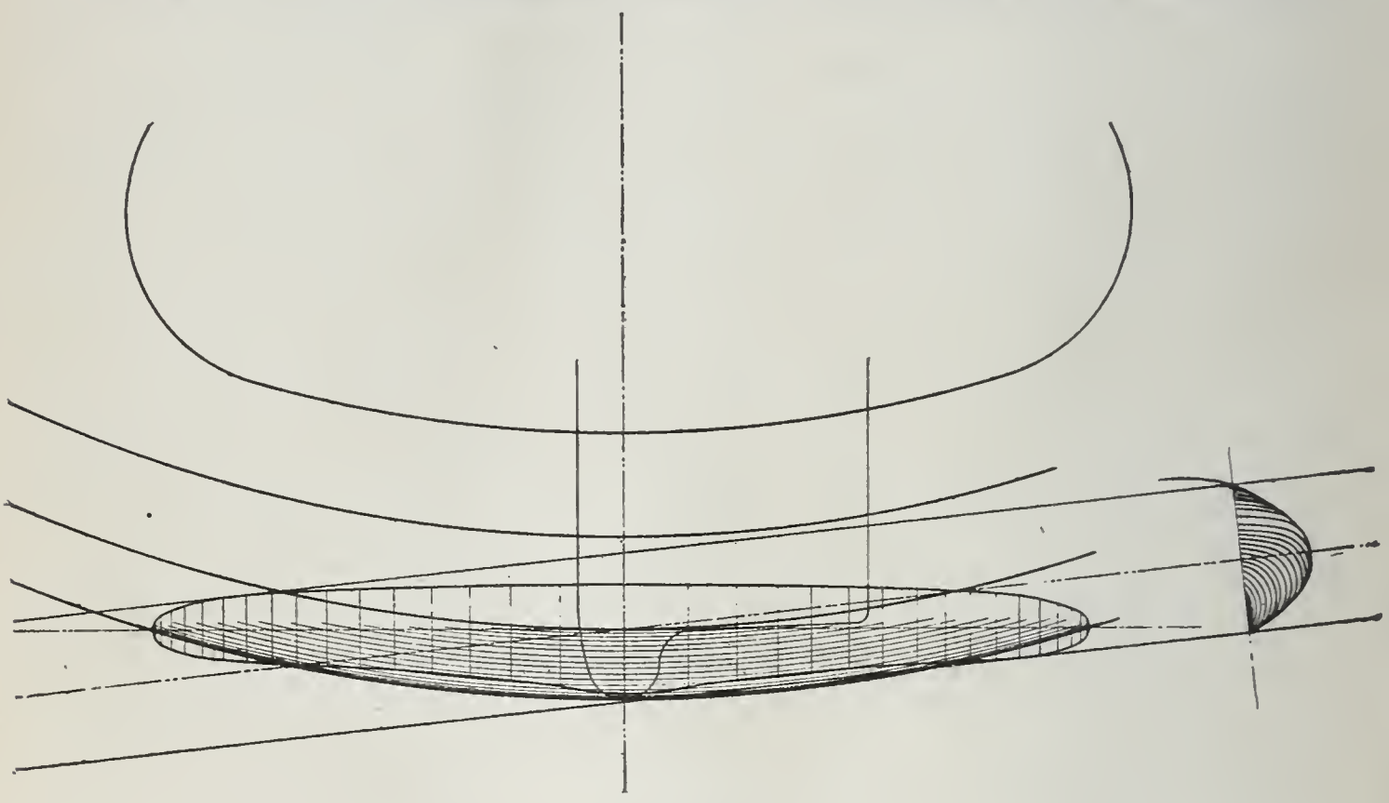


Diagram 1.

groove. If we divide the part of the flange in the groove into a number of vertical sections and project each one of these sections into one plane in the direction of the angle of the groove, or rather on concentric circles struck from the center of the curve, as shown in Diagram 1, we can draw a curved line tangent to the under side of these projected sections, and this curved line is the contour or shape of the groove, which the rail must have to allow the flanges to pass through. Observing the course taken to arrive at the result, we find that this result depends, leaving aside for the present the peculiar shape of the flange, on

(1) The width of the flange.
(2) The depth of the flange.
(3) The diameter of the wheel.
(4) The radius of the wheel.
(5) The wheel base; *i. e.*, distance between centers of axles.

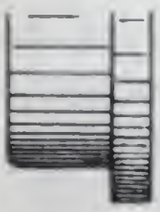


Fig. 3.

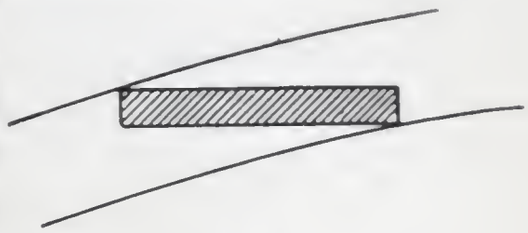


Fig. 4.

Were the flanges of the wheels rectangular, as shown in Fig. 3, we would arrive at a groove, the sides of which would be parts of ellipses, (Fig. 5) the bottom a straight line tangent to the lowest part of these ellipses. The section A. B. of Fig. 2 would be a rectangle (Fig. 4), and the width of the groove calculable. I append the formula for the width of the groove: Taking a wheel of the diameter (d), (Fig. 6) a square flange of a width (a) and depth (b), we get first $\frac{1}{2}$ the side of the section on the tread line $b' = \sqrt{b(d \times b)}$.

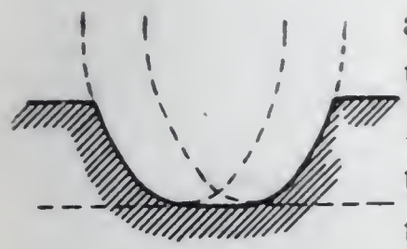


Fig. 5.

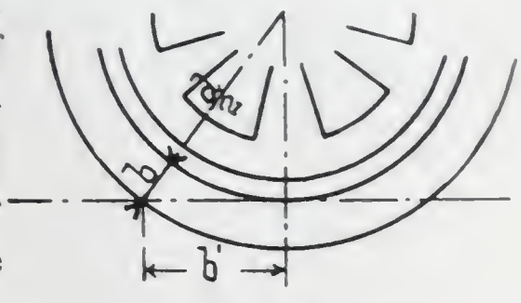
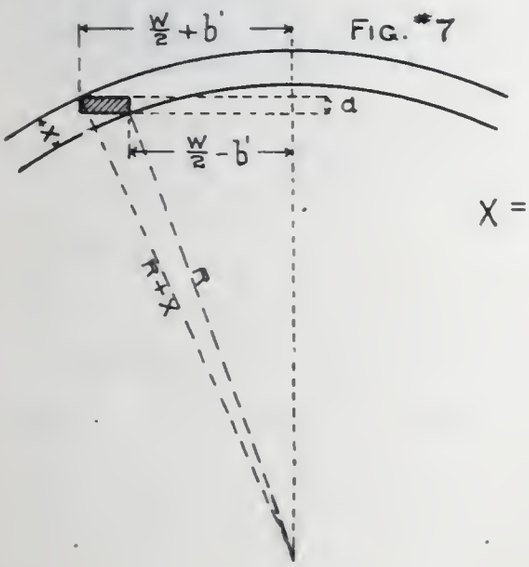


Fig. 6.



THEN

$$(R+X)^2 = \left(\sqrt{R^2-\left(\frac{W}{2}-b'\right)^2}+a\right)^2+\left(\frac{W}{2}+b'\right)^2$$

and

$$X = -R+\sqrt{\left[\sqrt{R^2-\left(\frac{W}{2}-\sqrt{b(d+b)}\right)^2}+a\right]^2+\left[\frac{W}{2}+\sqrt{b(d+b)}\right]^2}$$

Fig. 7.

Placing this section in a curve of the inside radius R at a wheel-base W. (Fig. 7.)

If the shape of the flange was a regular curve, the rectangle inscribed in the section at the tread line (see Fig. 8) could be found by another calculation, and the width of the groove found from this by a similar formula. But, as the shape of the flange is an arbitrary one, and its contour not a geometrical line of known properties, it is practically impossible to arrive at the result by calculation. It is possible, graphically, as demonstrated, but taking into consideration the many combinations of the factors in practical use, and that a large scale, probably double natural size, in every case would have to be employed, and further considering the chances of inaccuracies, due to large and unwieldy instruments, an investigation by these means seemed impracticable.

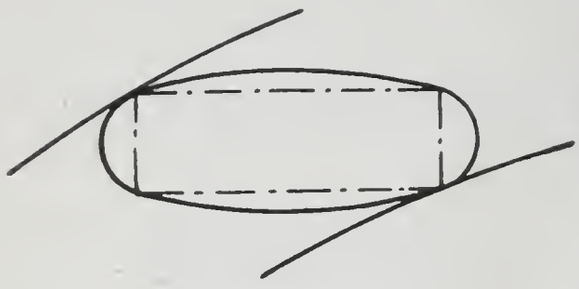


Fig. 8.

Worn rails did neither recommend themselves as a basis for investigation, as in them the grooves had necessarily become wider than they naturally should be, and the wheels, therefore, were not guided by them in a proper relative position. That is, the wider groove would allow the wheels to stand across it on a greater angle than it did on the original rail, only one side of the flange touching, as shown in Fig. 9. I therefore

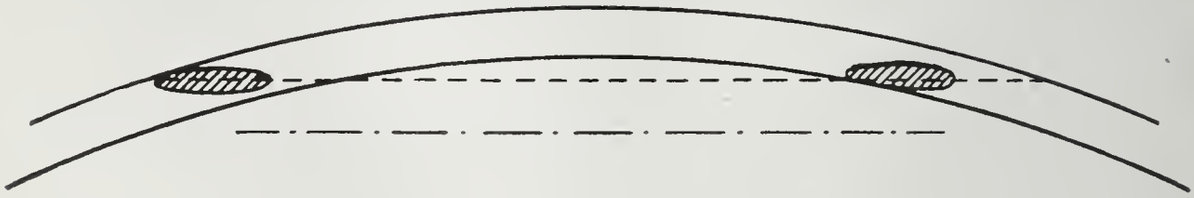
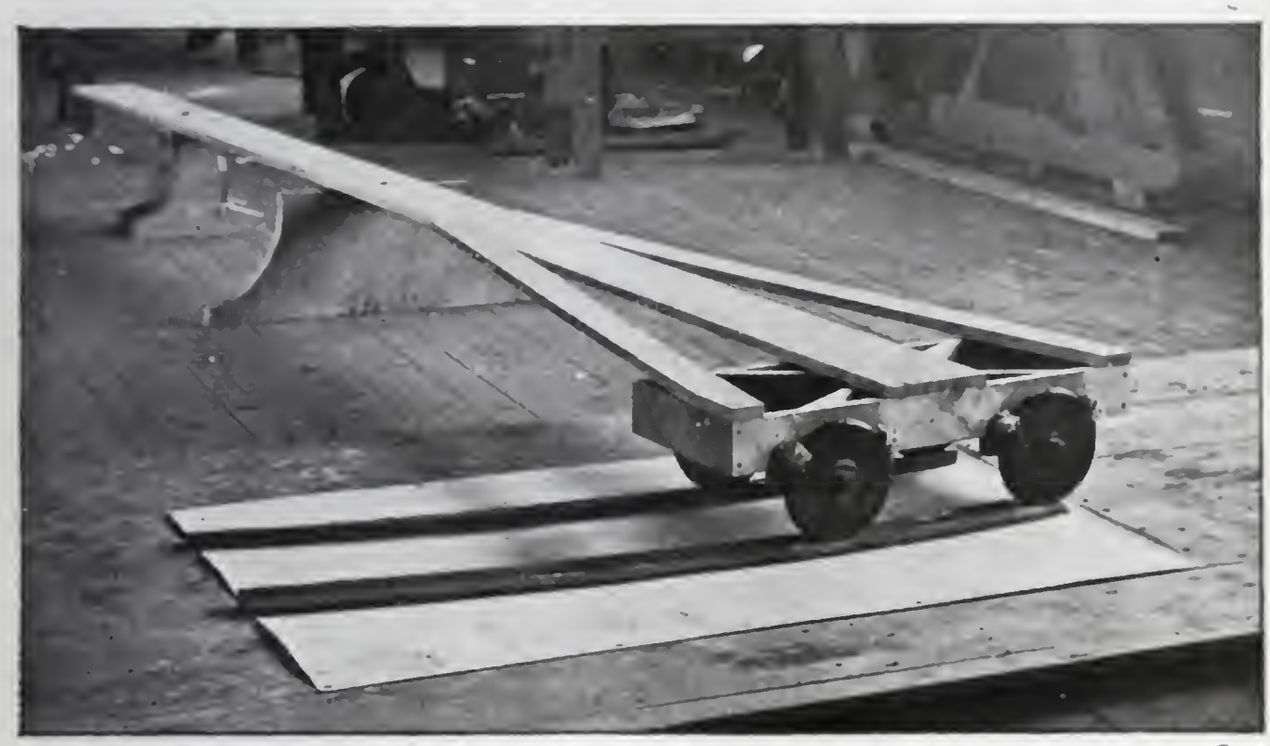


Fig. 9.

concluded that the best way would be to experiment with a small set of wheels, letting them shape their own groove in some soft, yielding material, and a casual test of results by simplified theoretical calculations and graphical laying out shows that they are quite accurate enough for all practical purposes.

The apparatus used for these experiments is shown in the accompanying illustration. Two pairs of wheels were carefully turned out of hard wood to accurate scale (of 3 inches to 1 foot)

and with their axles, on which they were turned, secured to a strong frame, representing the truck, so that they could revolve freely, but without any play whatever. The frame was rigidly fastened in the center to a stiff board, extending at right angle with the truck, to what would be the center of the curve. A pin accurately turned and fitting snugly in holes in the board and holes in a wooden stand screwed to the floor, formed the center proper. A large piece of drawing paper was stretched on a board, and on it were laid rail planks (without any groove) formed out of potter's clay, following the curves described by thewheels,



Apparatus for Determining the Correct Groove in Guard Rails.

when allowed to move, guided by the board from the center of the curve to whatever radius it was set. The wheels were then set upon the rail blanks and weighted until their flanges sank into the clay to their full depth, at which point the whole apparatus was arranged to be exactly level. The wheels, having previously been varnished, were thoroughly oiled so that the clay would not stick to them. The first pair of wheels was then revolved from the axle by hand, and thus the truck moved along the potter's clay, the flanges cutting their own grooves into it. The length of arc available having been traversed, the truck was lifted away, and, if a perfect impression had been obtained, short

pieces were cut out of various parts of the arcs of both the inner and outer rail, and particularly of those parts which had been traversed by the front wheels only, or the hind wheels only, and those that had been passed over by both wheels, as comparison of them would show whether or not the truck stood exactly square with the radial line, and on account of some peculiarities yet to be mentioned. These pieces were cut out so that the cut would also sever the paper underneath and extending a short distance inside and outside, forming a strip on and by which the cut-out piece could be slid away on to another board and put away to dry and harden without handling the piece itself while yet soft, thereby avoiding possible distortion, except on the very ends, by the cutting knife. As this latter was unavoidable, the pieces, after being thoroughly hardened, were sawed in half, so as to get at the

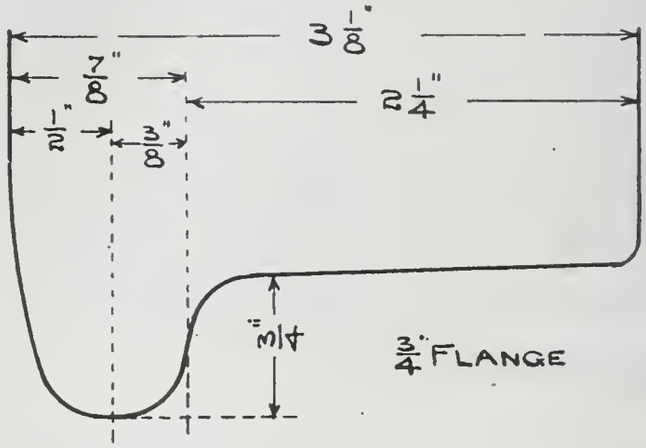


Fig. 10.

central undistorted section, and the sawed surface ground smooth on a piece of slate, so as to present sharp lines. The shrinkage of the clay in drying could well be neglected, as actual measurement on a test piece showed that it would amount to little more than one sixty-fourth of an inch in the full-size width of the groove.

In this manner over 125 good sections were obtained, all apparently faulty or doubtful ones having been discarded, and several being duplicates and triplicates, so as to prove each other. These sections represented various combinations of the factors influencing the shape and size of the groove. Starting out, in regard to shape, with the most prevalent flange for electric cars, shown in Fig. 10, the following dimensions and meas-

urements of these factors, representing various conditions, and sizes in actual use on street railways, entered into the experiment:

(1) Width of flange, $\frac{5}{8}''$—$\frac{3}{4}''$ and $\frac{7}{8}''$.
(2) Depth of flange, $\frac{3}{4}''$—$\frac{7}{8}''$ and $1''$.
(3) Diameter of wheel, $33''$—$30''$ and $27''$.
(4) Radii of rail, - $30'$, $35'$, $40'$, $45'$, $50'$, $55'$, $60'$, and $65'$.
(5) Wheel base, - $6'$—$6'6''$—$7'$—$7'6''$.

Representative sections were selected of those obtained, and sharp scribings of them enlarged by pantograph to full size. Some of these are shown on page 70.

Before, however, going into the details of these sections, we must consider another factor which somewhat affects the conclusions to be arrived at, and that is the gauge. By again referring to Fig. 1, we see that, with the aid of the graphically laid-out section of the flange on the tread line, and the also graphically determined points where the arcs struck from a common center would tangent these sections when placed in proper relative position in the curve guided by the wheel base and the gauge to which the wheels are set on the axle, it is quite easy to calculate the correct gauge of the track left by the wheels, it being the difference between the radius of the innermost circle (which in all the experiments was the line to which the radius referred) and the radius of the outer circle. This difference, of course, varies with the variation of any of the factors determining the width and shape of the groove; it is, however, most affected by the radius, while all the other factors, within their practical limits, affect it so little that they may well be neglected. Therefore it can be said that, comparing the corrected gauge of the track with the wheel gauge, for the gauges $4'\ 8\frac{1}{2}''$ to $5'\ 4\frac{1}{2}''$, size of wheels, flanges and wheel bases being those in common use on street railways, the former is from $\frac{3}{8}''$ to $\frac{1}{8}''$ greater than the latter between the limits of $30'$ and $60'$, the wheel gauge being measured between the lowest points of the fillets running from the tread to the flange, the track gauge being measured between the extended sharp corners of the groove at the tread, as shown in Fig. 11.

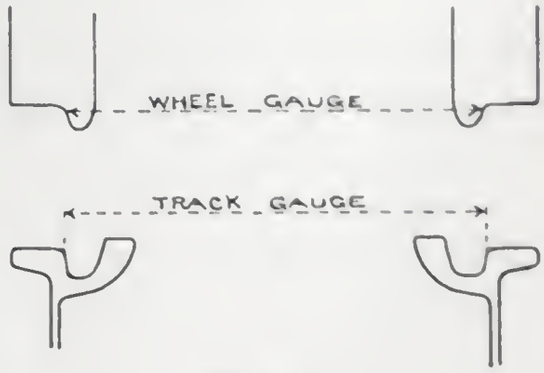
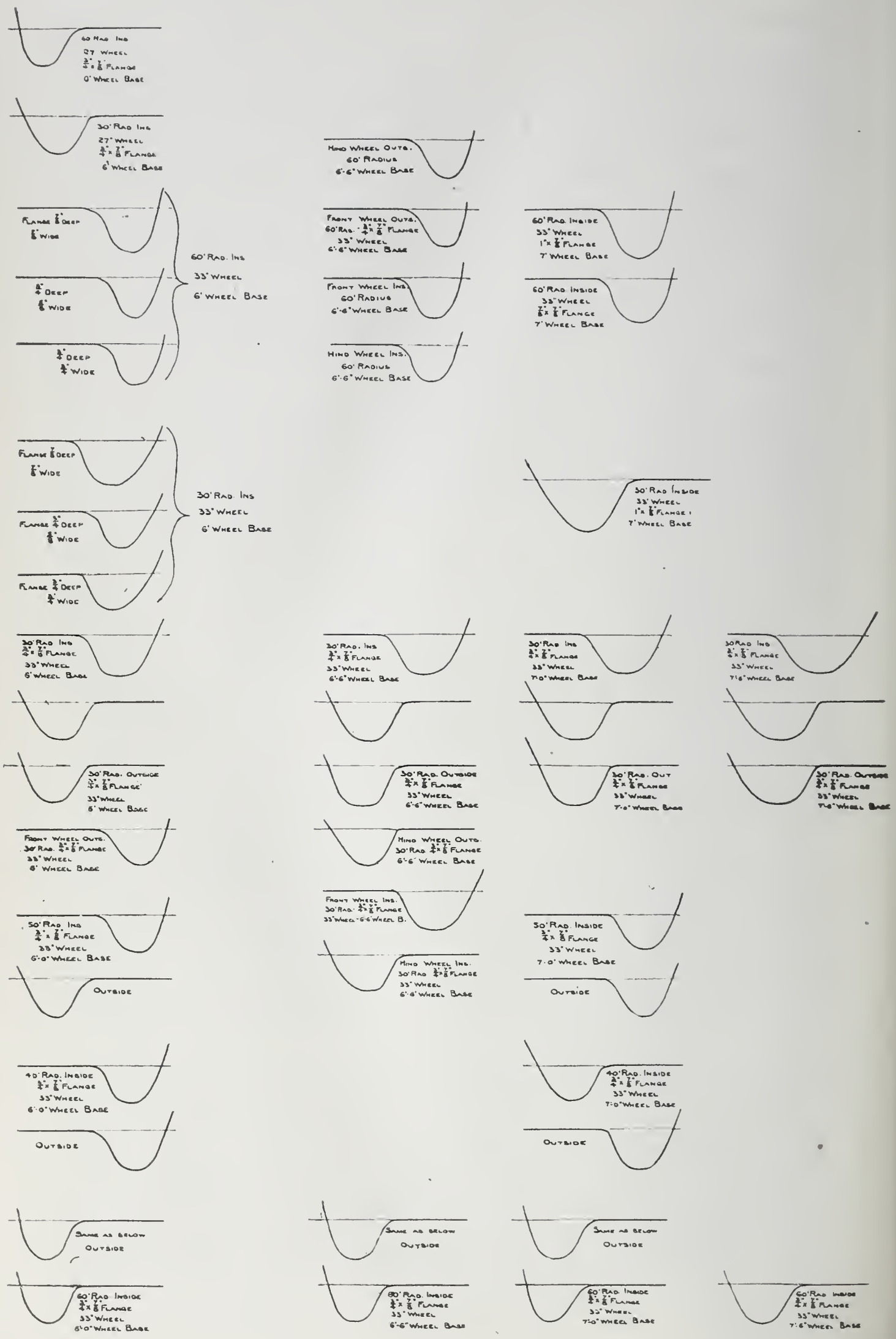


Fig. 11.


60' Rad. Ins
27" Wheel
6' Wheel Base
30' Rad. Ins
27" Wheel
6' Wheel Base
Hind Wheel Outs.
60' Radius
6'-6" Wheel Base
Front Wheel Outs.
33" Wheel
6'-6" Wheel Base
60' Rad. Inside
33" Wheel
7' Wheel Base
Front Wheel Ins.
60' Radius
6'-6" Wheel Base
60' Rad. Inside
33" Wheel
7' Wheel Base
Hind Wheel Ins.
60' Radius
6'-6" Wheel Base
60' Rad. Ins
33" Wheel
6' Wheel Base
30' Rad. Ins
33" Wheel
6' Wheel Base
30' Rad. Inside
33" Wheel
7' Wheel Base
30' Rad. Ins
33" Wheel
6' Wheel Base
30' Rad. Ins
33" Wheel
6'-6" Wheel Base
30' Rad. Ins
33" Wheel
7'-0" Wheel Base
30' Rad. Ins
33" Wheel
7'-6" Wheel Base
30' Rad. Outside
33" Wheel
6' Wheel Base
30' Rad. Outside
33" Wheel
6'-6" Wheel Base
30' Rad. Out
33" Wheel
7'-0" Wheel Base
30' Rad. Outside
33" Wheel
7'-6" Wheel Base
Front Wheel Outs.
33" Wheel
6' Wheel Base
Hind Wheel Outs.
6'-6" Wheel Base
Front Wheel Ins.
33" Wheel
6'-6" Wheel B.
50' Rad. Ins
33" Wheel
6'-0" Wheel Base
50' Rad. Inside
33" Wheel
7'-0" Wheel Base
Outside
Hind Wheel Ins.
33" Wheel
6'-6" Wheel Base
Outside
40' Rad. Inside
33" Wheel
6'-0" Wheel Base
40' Rad. Inside
33" Wheel
7'-0" Wheel Base
Outside
Outside
Same as below
Outside
Same as below
Outside
Same as below
Outside
60' Rad. Inside
33" Wheel
6'-0" Wheel Base
60' Rad. Inside
33" Wheel
6'-6" Wheel Base
60' Rad. Inside
33" Wheel
7'-0" Wheel Base
60' Rad. Inside
33" Wheel
7'-6" Wheel Base

The $\frac{3}{8}''$ difference is for a wheel base of 7′ 6″ on a mean gauge of 5′ 0″ with 33″ wheel and $\frac{7}{8}''$ deep flange; on a 6′ wheel base this would be reduced to about $\frac{5}{16}''$. It might, however, be mentioned that a further increase of the wheel base would bring us to a maximum beyond which the difference would diminish again. This maximum, with the above gauge and wheel and 30′ radius is, at about 8′ wheel base, where the radial lines drawn from the tangent points of the circles fall into one common line, as shown in Fig. 12.

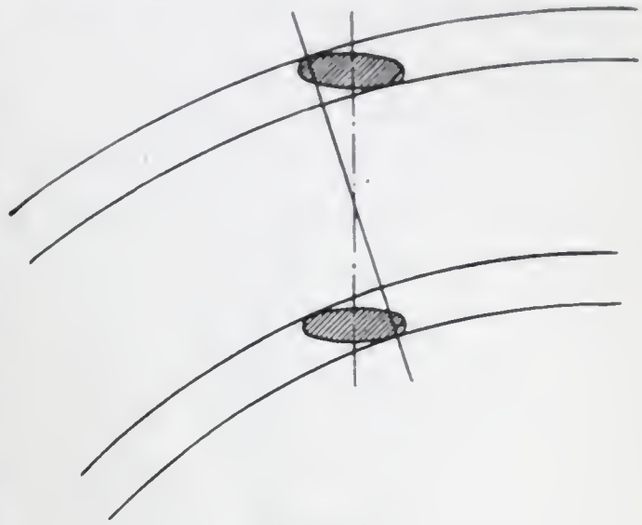


Fig. 12.

Careful measurements, taken in connection with the experiments, substantiate the calculations, which are also borne out by the fact that wheels set $\frac{1}{4}''$ tighter than the track gauge will run through curves of 33′ radius, laid to exact gauge, without binding.

The exact setting of the wheels on their axles has not had the careful consideration that wheel-makers and car-builders should give it, and yet it is so essential to the proper working of the wheels on curves and switches. Not only is accuracy and uniformity of setting necessary, but a standard as to the amount of clearance between wheel gauge and track gauge should be adhered to. We find this clearance on some roads $\frac{1}{4}''$, on others as much as $\frac{1}{2}''$. The former seems quite sufficient for street railways, and, in fact, will make cars run smoother on the straight track, on account of not allowing so much side sway, which is sometimes quite noticeable on fast-running electric cars. But while on straight track any greater clearance does, at least, no special harm; on curves it becomes of vital importance, and so long as there is no standard, curves should be laid with reference to the wheel gauge in use on the road, with an allowance for inaccuracies in setting of the wheels. A standard wheel flange for electric roads in cities is a further long-felt want, but argument in favor of its adoption is not within the scope of these lines. In the consideration of the sections derived from the experiments,

to arrive at the most desirable section of groove in guard rails, we must take the flanges as they now are in use and make a further allowance for a variation in their size due to the manufacture.

Before going into the details of the shape of the groove, we will consider the width as measured on the level of the head. Measurements taken for this on the sheet would, however, be on a line with the tread of the wheel, which, in practice, is never made exactly parallel to the axle, but has a slight draft; that is, the wheel is not exactly cylindrical, but slightly conical, while the head of the rail is made as nearly horizontal as possible. This practice, while I believe it has its origin in the desire to facilitate the manufacture of the wheels, has advantages, on which account it would not be well to discard it. It ensures the contact between the wheel and the rail at or near the gauge line from the beginning, which, in turn, ensures safety and easy running and tends to center the car; that is, prevent side motion and keeps the flanges away from the side of the rail on the straight track. For the same reasons, the side of the head is not made to follow the lines of the flanges of this wheel, but is made more vertical. The difference, however, calls for a correction of the width of the groove when measured on a level with the head of the rail from the width given on the sheet, amounting to $\frac{1}{32}$ inch more on sharp curves, while on long radius curves it can be neglected.

A glance at the flange sections, previously shown, will convince that the differences in the widths are too great to compensate for all of them in one rail. It must, therefore, first be determined how many different widths of groove will be necessary in practice. For this purpose I have tabulated the results of my experiments in the shape of Diagram No. 2. I have eliminated, however, in this the diameter of the wheel as a neglectable factor, the difference in the width of the groove for 6″ in the diameter of the wheel (27″ to 33″) being only $\frac{1}{32}$″ in very sharp curves and practically nothing in long radius curves. A 33″ wheel, *i. e.*, the largest wheel in practice, was used in most of the experiments, as a groove wide enough for it would certainly be wide enough for the smaller sizes, and the difference will provide merely for a

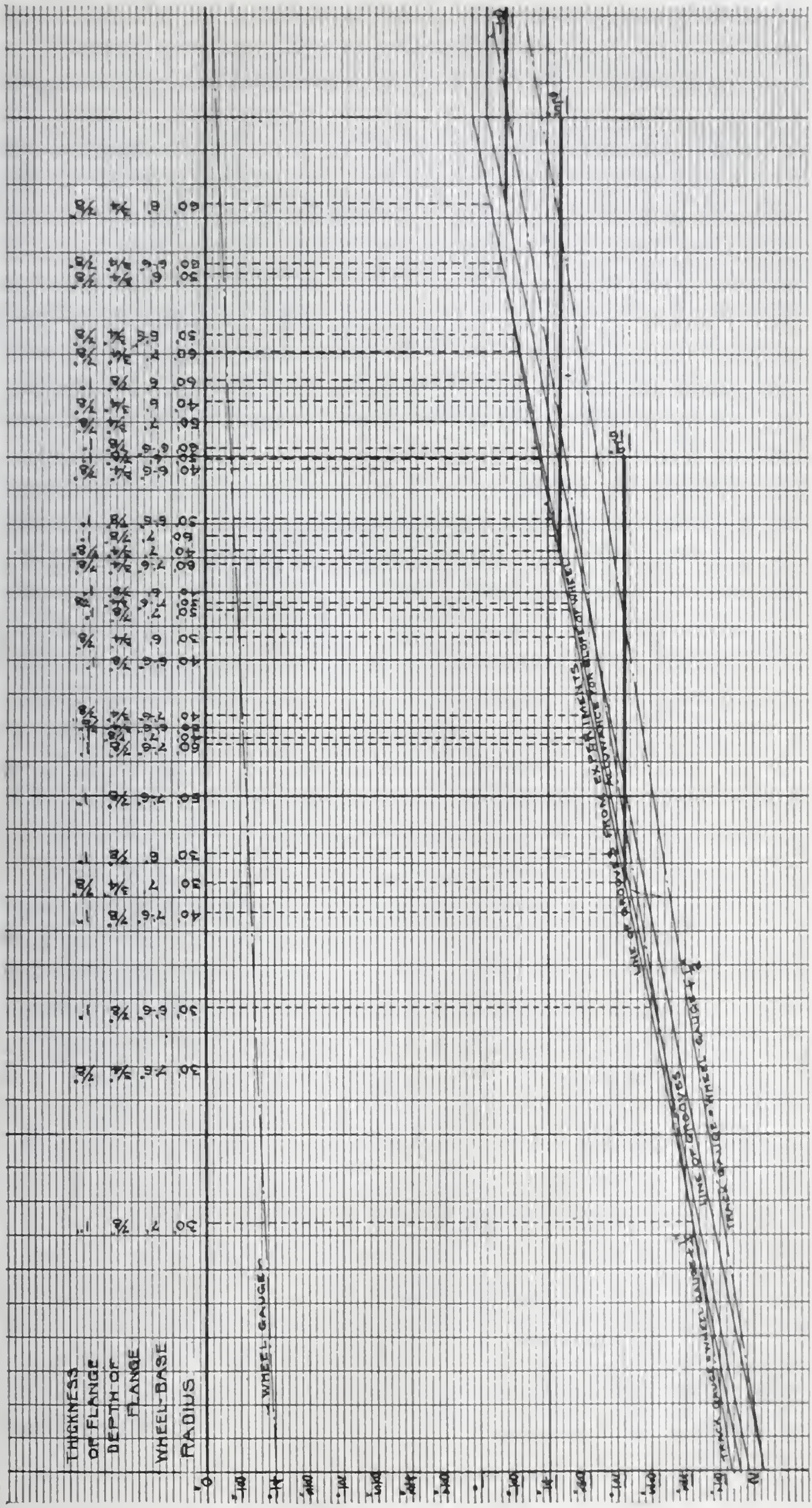

THICKNESS OF FLANGE
DEPTH OF FLANGE
WHEEL-BASE
RADIUS
WHEEL GAUGE
LINE OF GROOVES FROM EXPERIMENTS
ALLOWANCE FOR BLOPE OF WHEEL
LINE OF GROOVES
TRACK GAUGE = WHEEL GAUGE + 1/2"
TRACK GAUGE = WHEEL GAUGE + 1/2"

DIAGRAM 2.

very small extra allowance for variations. While further it was not convenient in the experiments to use larger flanges; these larger flanges, viz.: $\frac{7}{8}''$ deep, $1''$ thick had to be taken into consideration as being in practical use, and the increase in width of the groove arrived at by analogy from the increase or decrease produced by the various thicknesses and depths of flanges used in the experiments. The intermediate sizes could also well be eliminated and the smaller sizes discarded, as in practice, representing worn flanges, which, for self-evident reasons, could not be considered.

Starting from the heavy horizontal top line as a base, which might be said to represent the gauge line of the rail, the widths of the groove for the various radii, wheel bases and sizes of flange given, are measured by the scale of the paper on the dotted vertical lines to the first full line, marked "Line of Grooves from Experiments;" the second full line below it represents the allowance or correction to be made for the width measured on the level of the rail, against the measurement on the slope of the wheel tread. The third full line, marked "Line of Grooves," gives further allowance for the inaccuracies in setting of the wheels and thickness of the wheel flanges. It may be considered as representing the width of the groove, which should come into practical use. The light broken line near the base line represents the position in the groove of the point on the wheel directly under the center from which the wheel gauge is measured. The vertical distance between this line and the base line is, therefore, equal to one-half of the difference between the wheel gauge and the gauge to which the rails should be laid on curves of the radii in combination with the wheel base and size of flanges given above the base line. A curve laid to one-quarter inch wider than the wheel gauge, or one-half inch wider, as is the practice, will, therefore, not be correct, and if we lay off the amount of this incorrectness, plus or minus, vertically from the line of groove, we arrive at the two lowest broken lines. These lines represent the lines of touch of the wheel flange on the guard; that is, in a rail with a width of groove measured to this line below any of the given combinations of radii, wheel bases and flanges, laid to a gauge as much wider than the wheel gauge as the line is drawn

for, the flange of the inside front wheel and the outside hind wheel will touch the guard at the same time when the opposite wheels begin to bear against the treads. By taking these lines as a base, we can read off from the diagram how much wider than the wheel gauge a curve of the given radius in combination with the wheel bases and sizes of flanges must be laid for any fixed width of groove to make the guard effective.

Taking a $\frac{7}{8}''$ wide flange and allowing the track to be laid to $\frac{1}{4}''$ wider than the wheel base and allowing another $\frac{1}{8}''$ for the variations of setting, etc., we find that even on straight track, or very slight curve, a groove of $1\frac{1}{8}''$ is about the narrowest we should consider. Drawing the first heavy black horizontal line for this width of groove, and extending this we find that it carries to the line of groove at 60′ radius 6′ W. B. and $\frac{3}{4} \times \frac{7}{8}''$ flange with the track, however, laid only $2 \times \frac{1}{16} = \frac{1}{8}$ wider than the wheel gauge; if we lay the track at this same combination $\frac{1}{2}''$ wider

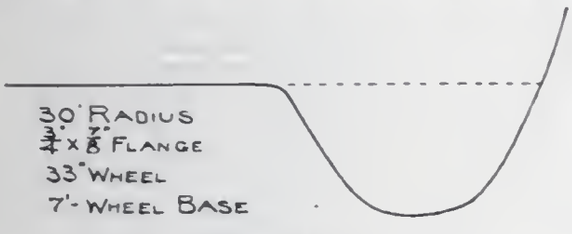


FIG. 13.

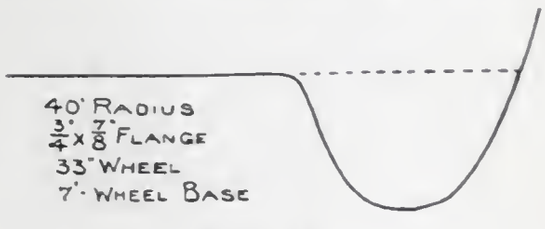


FIG. 14.

than the wheel gauge, it would necessitate a groove $1\frac{5}{16}''$ wide. As this width of track gauge had better not be exceeded, unless absolutely necessary, this can be taken as the second line of groove or the first for guard rails for curves.

This line carries to $40' - 6'\ 6'' - \frac{3}{4} \times \frac{7}{8}$ laid to about $\frac{7}{8}''$ more than the wheel gauge. If at this point we go again to a track gauge $\frac{1}{2}''$ wider than the wheel gauge, we arrive at a groove slightly less than $1\frac{1}{2}''$; this, however, carried further, does not seem to cover sufficiently the combinations calling for a wider groove. We might, therefore, allow the gauge to be slightly wider and go to $1\frac{9}{16}''$ groove, which would then carry, on a pinch, to $30' - 7' - \frac{3}{4} \times \frac{7}{8}''$. All combinations above that are so rare that they could probably be provided for by planing out the groove to a greater width, should they be called for. This would leave the two widths $1\frac{9}{16}''$ and $1\frac{5}{16}''$ as apparently desirable widths of grooves to be rolled in guard rails for curves.

Referring again to the sheet of sections, page 70, derived from the experiments, these two widths can be regarded as best represented by the two shown in Figs. 13 and 14.

While there are several others with nearly the same width, the above were selected on account of having the largest slant, *i. e.*, flatter curve on the guard side, which comes into consideration in determining the height of the guard.

The guard might be considered as a plane thrown in the path of the wheel to deflect it and thereby force it to follow the curve.

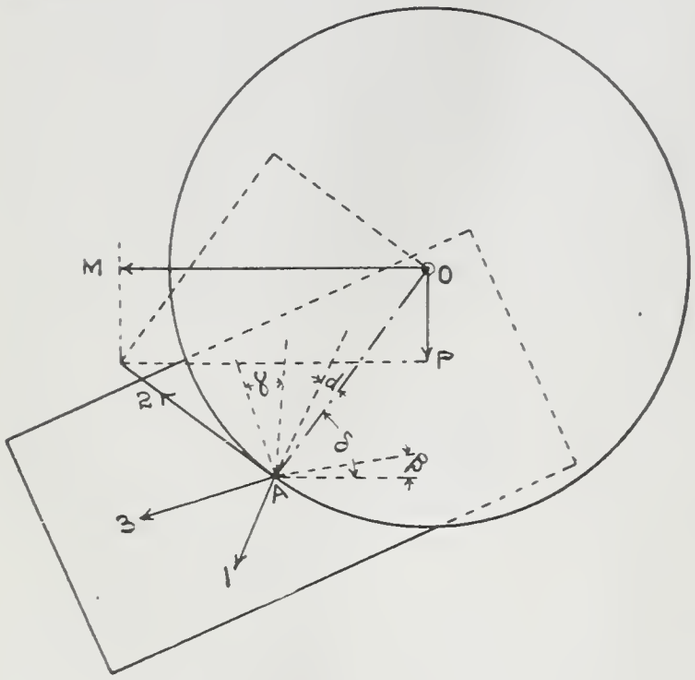


Fig. 15.

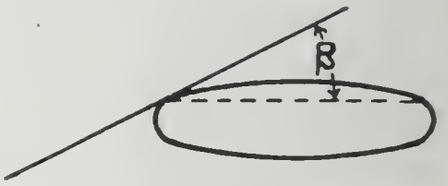


Fig 16

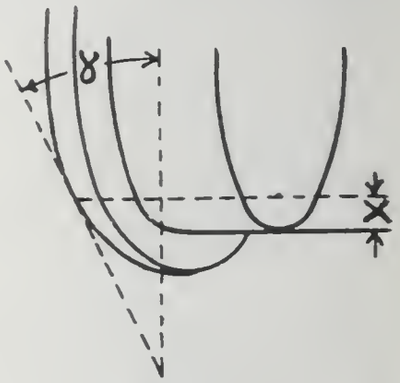


Fig. 17.

If a car were started in a curve by revolving the wheels, as is the case on electric cars, it only requires a very slight obstacle to overcome the traction, *i. e.*, the friction of the wheels on the rails, so that the wheels would either slip or be deflected before the car would mount the obstacle. A $\frac{3}{4}''$ deep flange on a 33″ wheel will strike any obstacle thrown in its path at the level of the tread sufficiently ahead of the center, even if at right angles with the wheel, to produce an angle of contact larger than the angle of friction between cast iron and steel, so that the wheel could not mount; providing, of course, it does not catch

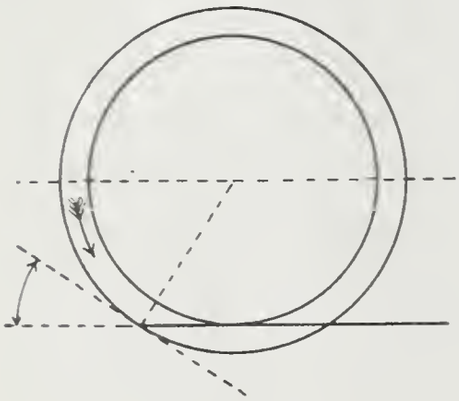


Fig. 18.

in any nick or abrasion. (See Fig. 18.) It is different if a car is pulled and the force acts horizontally on the axles instead of on the circumference of the wheel; then the point of contact becomes a fulcrum or point of leverage (Fig. 19), and it only depends on whether the pull is sufficient to lift the weight of the car, including the rolling friction, with the leverage established by the point of contact.

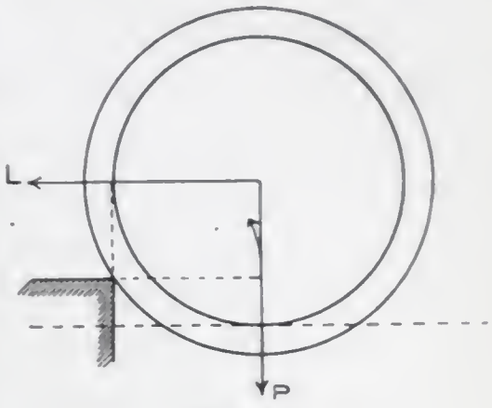


Fig. 19.

The same, of course, applies to a car under a momentum, the momentum taking the place of the pulling force. The momentum M and the weight of the car P combined will give a resultant force acting on the axle. A component OA of this force will be resisted by the guard at the point of contact A (Fig. 15), between the flange of the wheel and the guard. If this component is spent entirely in the friction of the wheel on the inclined plane, then, if the other component is in favor of the weight, the car will come to a stop; if it is, however, in favor of the momentum and sufficiently large to overcome the rolling friction, then the car will roll up on the inclined plane in the direction of the arrow 2. If, however, the angle of contact α between the first component and the inclined plane is less than the angle of friction between the substances of the wheel and the guard, then another force will result in the direction of arrow 1. This, combined with the balance of the momentum, acting in direction of arrow 2, will give the deflecting force, arrow 3. If this falls into a horizontal line, or below it, then the car will follow the guard without lifting. This depends on the momentum, or rather the combined force of momentum and weight, and on the angle α, which latter must be less than the angle of friction. The larger the momentum for a given weight, the smaller must angle α be to produce the deflecting force in the required direction. The angle α again depends on the horizontal angle β (Fig. 16) of the plane ofthe wheel and the line of the groove at the point of contact and the angle γ (Fig. 17), which the inclined guard forms with the vertical. It would, of course, be impossible,

within the practical limits, to provide for any momentum, no matter how large, but we must rather seek the limit of safety only just above the limit of possibility of deflection and gauge the speed of the car producing the momentum, so as not to exceed this limit. As angle β, *i. e.*, the horizontal angle between the plane of the wheel and the groove, as shown in Diagram 1 and Fig. 1, with the wheel bases and radii in practical use is always smaller than the angle of friction, angle γ would always be larger than the angle of friction if α represents the latter. If, therefore, we would assume angle γ equal to the angle of friction we would introduce a factor of safety which would increase as angle β decreases, *i. e.*, as the radius of the curve increases. As the groove produced by the experiments represents a section of the wheel on a plane at right angles with the plane of the guard at the point of contact, a line drawn on the angle γ = the angle of friction—tangent to the contour of the groove, will give, at the tangent point, the lowest point on the guard, which will give the above-mentioned slight factor of safety.

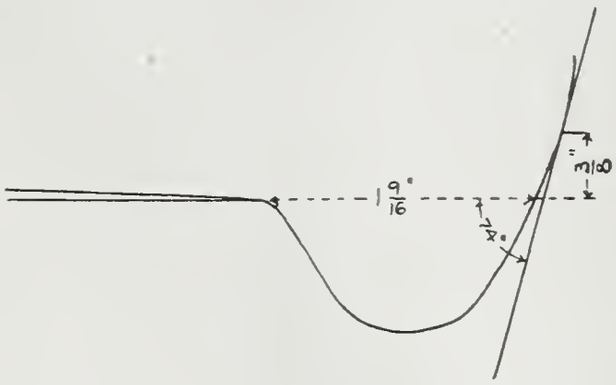


Fig. 20.

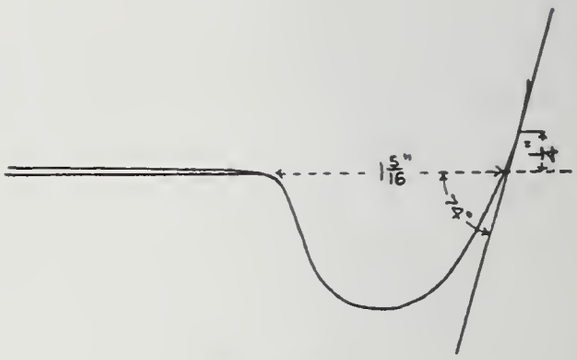


Fig. 21.

If we take the angle of friction between cast iron and steel as 16° (some authorities give it less than that), we find that the line will tangent the contour of the $1\frac{9}{16}''$ groove selected about $\frac{3}{8}''$ above the head of the rail, which, curiously enough, is exactly the height of guard which has heretofore been in almost universal use. On the $1\frac{5}{16}''$ groove this comes at $\frac{1}{4}''$, as shown in Figures 20 and 21.

It will be understood that if we use a guard of the thus obtained height above the tread, the wheel will be deflected on the smallest radius the groove is intended for, unless the momentum is so large that its component, tending to roll the wheel upon the

guard, is sufficient to overcome the deflecting power, *i. e.*, throw the direction of the action of the combined forces above the horizontal. Of course, such factors as irregularities in the guard, such as nicks, joints out of alignement or pieces broken out of the flange of the wheel, are not provided for, although the latter would not give the wheel much chance to catch if the guard is carried down on the line of wear, as the lower points of the flange, being in contact, would prevent the wheel from going over sufficiently for the sharp edge of the fracture to catch on the top of the guard.

If we use the same groove on a larger radius, but laid to such gauge that the flange will touch the guard, then the point of contact would be below the highest point on the line of wear, as will be seen by inscribing the groove, corresponding with 60′ rad. 7′-6″ wheel base, $\frac{3}{4}''$ x $\frac{7}{8}''$ flange into the $1\frac{9}{16}''$ groove corresponding with 30′—7′—$\frac{3}{4}$ x $\frac{7}{8}$ (Fig. 22), but the thereby resulting larger angle will be more than equalized by the smaller angle of impact β, producing an angle of contact α still smaller than the angle of friction.

Fig. 22.

We have, therefore, so far determined the desirable widths of groove and heights of guard. In regard to latter, it might yet be said that experiments in connection with the determination of the groove, although attempted, could necessarily furnish no criterion; first, on account of the difference of the material from the real; secondly, on account of the difficulty of obtaining and determining the necessary and exact momentum.

It now remains to determine the most desirable shape of the grooves, which must necessarily be modified from the grooves taken as a base on account of the various conditions; that is, combination of radii, flanges, etc., that each one is to be used with; secondly, to provide for a vertical wear of the rails.

In regard to the latter point, it is, of course, not desirable that the flange should bottom in the groove, as, while it would probably increase the life of the rail, it would also increase the friction, if both the tread and flange would bear, as one would necessarily have to slide, thereby increasing the power necessary to

move the car around the curve. It has been customary to make the groove 1″ or $1\frac{1}{8}$″ deep, and the latter depth seems about right, as with flanges $\frac{3}{4}$″ deep this would give a vertical wear of $\frac{3}{8}$″ before the flange bottoms, and it might well be assumed that by the time the head of the rail has worn down $\frac{3}{8}$″ the entire rail will practically be worn out.

We must, therefore, at once add $\frac{3}{8}$″ to the depths of the grooves taken as a base, which calls for a modification in the lower part of the contour. The upper part we want to hold as near to an average wear-line as we can, and to arrive at this average wear-line I have laid into one drawing the wear-lines of the various principal combinations with which the groove is to be used. Allowance should be made in this, however, that, as the groove will be theoretically wider than necessary for most of the cases, the wheels will stand across the groove at a slightly greater than the correct angle, thereby a larger radius, really producing a wear-line, which, theoretically, would belong to a smaller radius.

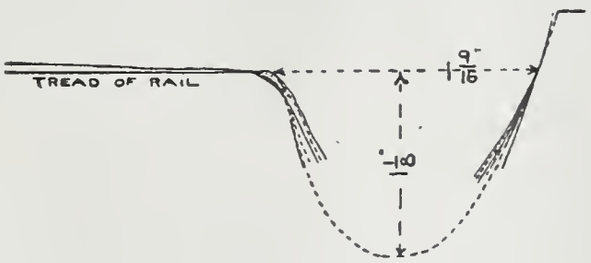


Fig. 23.

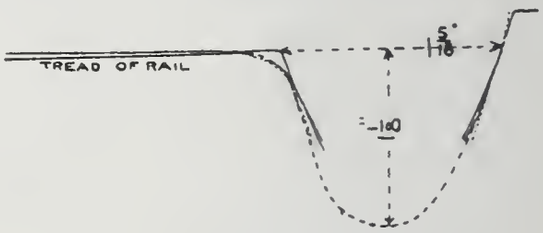


Fig. 24.

From this, as shown in Figs. 23 and 24, it would appear that very little modification is necessary on the guard side, taking into consideration that on larger radii, which are represented by the steeper, more nearly vertical lines, it would be permissible to have the flange strike somewhat lower down on the guard. It seems that extending the guard line of the base contour downward from a point about $\frac{1}{4}$″ below the tread so that it will join the bottom of the groove on an easy line, will give a compromise which will ensure a practical average wearing surface of $\frac{3}{4}$″ in width, extending about equally above and below the tread line on the $1\frac{9}{16}$″ groove and slightly less on the $1\frac{5}{16}$″ groove.

More modification seems necessary on the tread side. On sharp curves it will be noticed that the contour of the groove forms quite a sharp corner with the level of the head (Fig. 25),

while on larger radii a larger rounding appears; the reason for this being, that on short radii the gauge line of the wheel is moved so far inside the gauge line of the rail that the fillet of the wheel does not leave its impression, the sharp corner being cut by the extremity of the flange. On the specimens derived from the experiments, this sharp corner is most noticeable on the sections taken from the parts traversed by the inside front wheel or by the outside hind wheel alone, where the flange, touching the tread side in its upward movement, left this corner clear and sharp. On the other wheels, the sharp corner was partly smoothed out and rounded off in the yielding material by the tread of the wheel passing over it after it was formed. On larger radii this sharp corner theoretically still exists, but a part of the fillet having first left its impression, it lies in the rounded-off part, and is, therefore, not so noticeable.

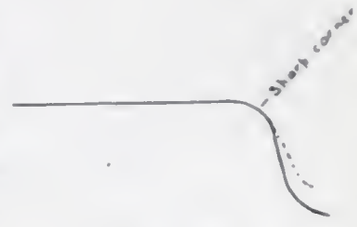
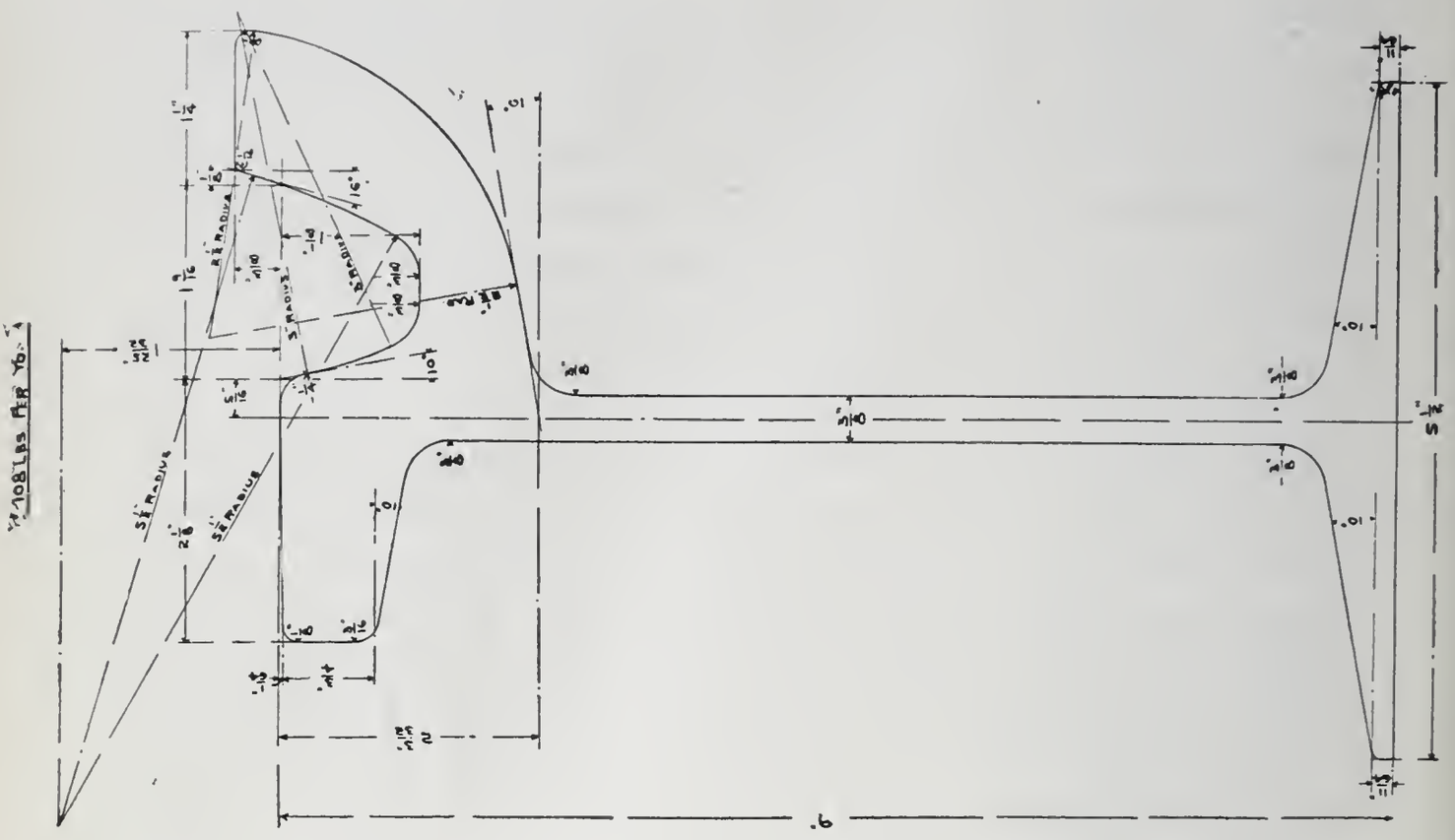
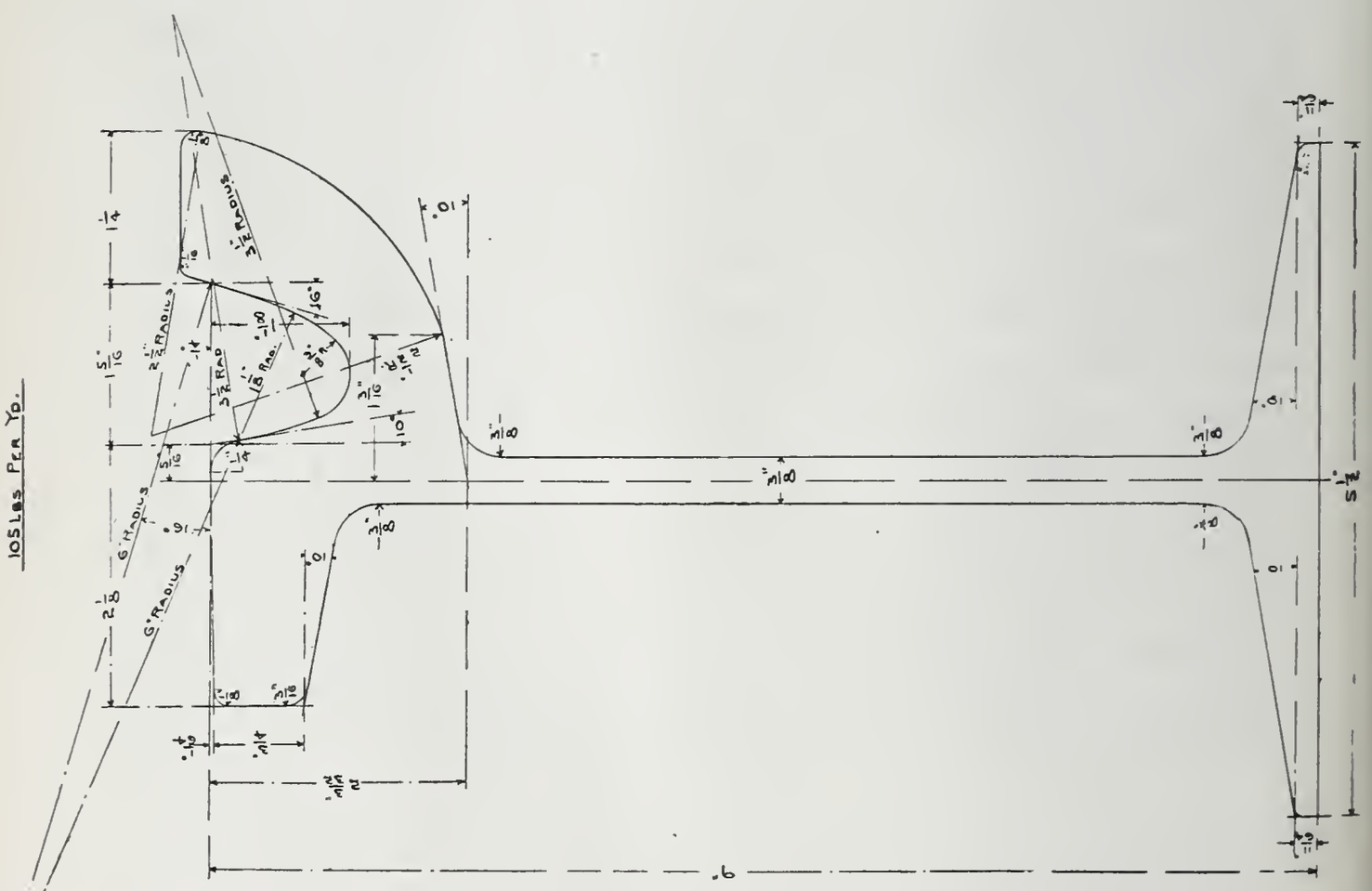


Fig. 25.

As this rounding is already quite noticeable on a 40′ rad., with a small wheel base, it is useless to keep this sharp corner, as it would be quickly ground away, except on very sharp curves or with very large wheel bases. Therefore, the contour of the groove had better be joined with the tread by an easy rounding. The decided slope of the wear line on the head side, shown by the contours taken as basis, seems further not desirable on account of matching badly with the straight-track rails, which are made more nearly vertical on this line, for reasons before stated; besides the fact, that larger radii call for less slope. It seems to recommend itself, therefore, to go to the extreme limit toward the vertical on this line, letting the guard on the other side take the greater part of the wear, joining the line as easily as possible with the bottom of the groove.

Having thus culled the undesirable from the desirable, the result is represented in the following two sections, which represent that which is likely to give best satisfaction.


108 Lbs Per Yd.


105 Lbs Per Yd.

DISCUSSION.

Mr. A. Langstaff Johnston.—When the contract for the Hestonville and Mantua Railway, of which I am president, was being let for new rails, these questions were fully discussed in detail at a meeting of constructing engineers from the principal eastern cities, called together for this purpose, and there was among them considerable difference of opinion as to the proper width of groove in guard rails.

Mr. James Christie.—With grooved rails on curves, could not the guard be dispensed with on the outer rail?

Mr. Angerer.—While it is not absolutely necessary, it gives greater safety to guard the hind wheel, and it distributes the wear more evenly between the inner and outer rail, the guard on the outside rail taking the wear which would otherwise come wholly on the tread of the inside rail. I therefore think it greatly preferable to retain the guard on the outside rail, at least on sharp curves.

Mr. William Wharton, Jr.—While rail-makers have given much attention to these details, the wheel-makers seem to have no regard to science, and often exhibit no common sense in the proportioning of wheels, and there is consequently no uniformity of practice. The flanges, which should be carefully smoothed, are often left rough, causing much unnecessary wear on the rails. This same result is also produced by bad mounting of the axles on the trucks.

Capt. Edward B. Ives.—The night line of the Tenth and Eleventh Street Railway in this city has been carefully studied to find out the action of the wheels upon the curves, and by careful measurement of current we have found that the proper shaping of the groove in the guard rail has resulted in considerable economy and improvement in running.

IV.

A PROBLEM IN HYDROSTATICS AND ITS INGENIOUS SOLUTION.

By C. H. Ott, Active Member of the Club.

Read, February 16, 1895.

In the course of an engineering practice, and on every piece of engineering work, there arise circumstances and conditions which call for treatment and manipulation, for which there are no established rules, records, or known precedents.

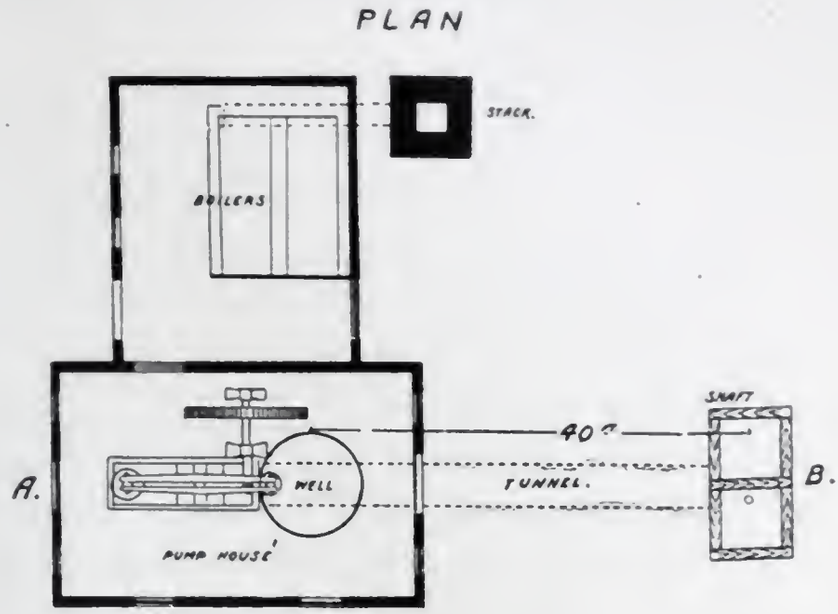
Such conditions call for the exercise, in the highest degree, of the faculty of ingenuity and invention, and it can be laid down as an axiom that the successful engineer is the one who can use to the best advantage such materials and appliances as are available and at hand, which will best meet the requirements of such conditions.

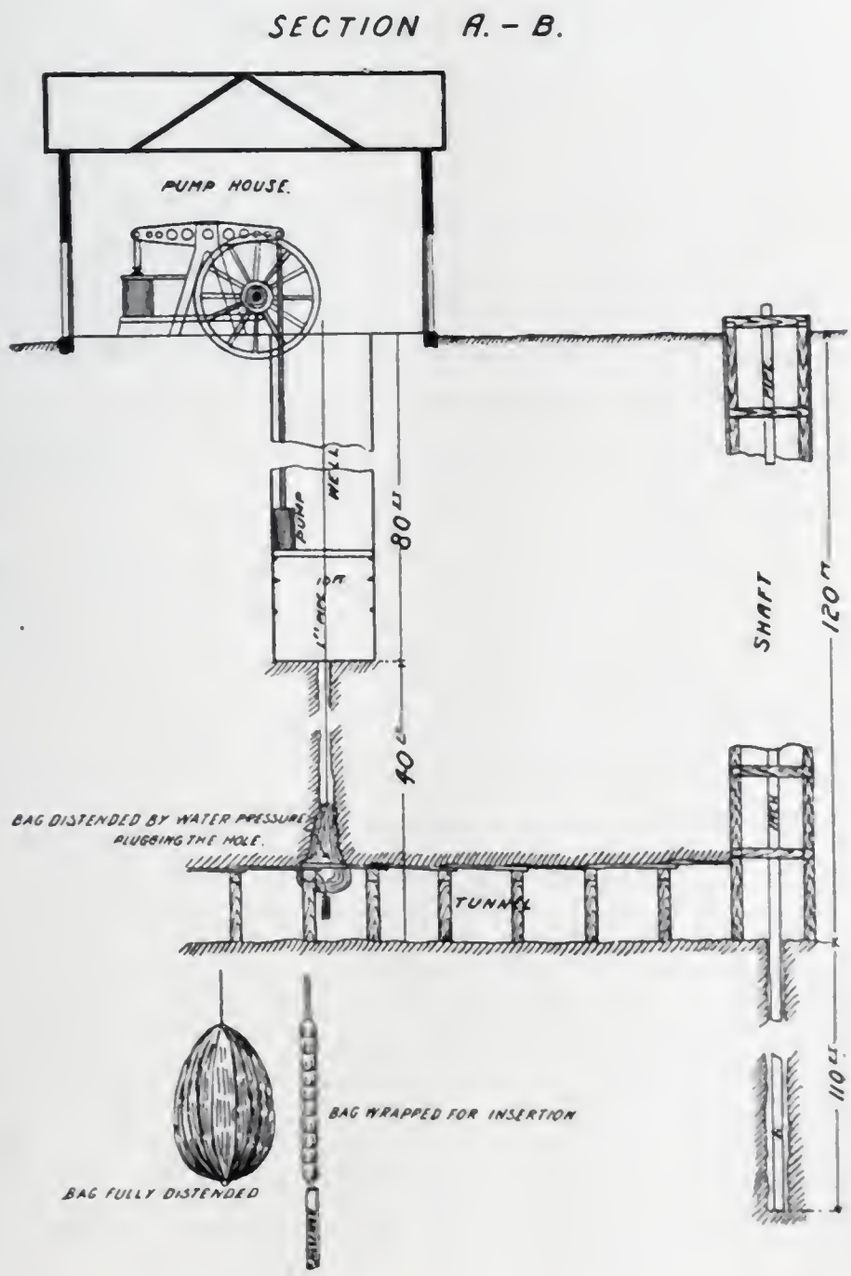
Several years ago, I had the pleasure of witnessing and assisting in the operation of a device planned and executed under such circumstances, and though the conditions under which it was called for and used can hardly occur again, yet a description may be of sufficient interest to submit before this Club.

In 1882 there was constructed in the town of Anniston, Ala., a system of water-works intended principally for the water supply and fire protection of the industrial works established in that town, and incidentally for a domestic water supply.

The works consisted of a well 10 feet in diameter (see illustration), cased with cast-iron rings bolted together in sections, and driven to a water-bearing strata 80 feet below the surface of the ground.

About 15 feet above the bottom of the well was a double-acting single cylinder pump, driven by a pump rod attached to the walking beam of a simple engine erected in the pump house built over the well. The pump delivered the water through a 10-inch main to an iron tank, in dimensions 30 feet in diameter and 40 feet in height, erected on a hill distant about a mile, and about 225 feet in elevation above the floor of the pump house


PLAN
STACK.
BOILERS
SHAFT
40 ft
A.
WELL
TUNNEL.
B.
PUMP HOUSE


SECTION A. - B.
PUMP HOUSE.
PUMP
WELL
80 ft
40 ft
SHAFT
120 ft
BAG DISTENDED BY WATER PRESSURE PLUGGING THE HOLE.
TUNNEL
110 ft
BAG WRAPPED FOR INSERTION
BAG FULLY DISTENDED

the mean pressure maintained at the pump house being about 90 pounds per square inch.

As the water service required at the time of the establishment of these works was not very heavy, the water supply from the well was sufficient for about twelve hours' supply in six hours of pumping, and the engine and pump had sufficient capacity to pump the well out to within 8 or 10 feet of the bottom in about twelve hours of continuous pumping.

When it became necessary to examine or repair the pump cylinder and fixtures, the water was lowered by pumpage to the greatest possible extent, and then, by means of a steam jet, the well was kept drained until such repairs were made.

In the course of a year or so, by reason of the great growth of the town, the supply from this well became entirely inadequate to the demand, and it was decided by the owners of the works to make an effort to increase the supply. Accordingly a new well was started about 40 feet east of the pumping well. A timbered shaft 6 by 12 feet was driven to a depth of 120 feet, at which depth a flow of water was had; the amount available being determined by the time required to empty the new shaft by means of a 3-inch steam jet and a Cameron pump with 4-inch delivery. In order to provide storage for water and to connect the new shaft with the pumping well, a timbered drift 4 by 6 feet was run from the new shaft towards the west, running directly under and about 40 feet below the bottom of the pumping well. The water supply not being deemed sufficient under these arrangements, measures were taken for drilling to a greater depth in the new shaft. Accordingly an 8-inch well, cased with pipe, was bored to a depth of 230 feet below the level of the pump house floor, and a great flow of water was struck. During the drilling, some trouble was experienced in loss of augers and sand pump, by the casing becoming jammed, and on account of the material which was passed through, being a disintegrated siliceous limestone.

In passing through the limestone the drill bored a much larger hole than 8 inches in diameter, and as a consequence the casing did not confine all of the water struck, large quantities of which passed up through the disintegrated materials outside the

casing. When the boring was completed at a depth of 230 feet, the quantity of water passing up on the outside of the casing was so great that the water level in the new shaft could not be lowered and maintained with the apparatus at hand to more than about 20 feet below the pump house floor.

In order to bring the new supply to the pumping well, an uncased hole, 8 inches in diameter, was drilled in the bottom of the pumping well to the drift below. This connection having been made, it was found impossible, with all of the pumps and jet apparatus available, to lower the water level in the pumping well to more than about 25 feet below the pump house floor, and an ample water supply for the time being was made available.

Several months after these arrangements had been completed, the pump failed to deliver water, and the cause was at once located in the pump cylinder, which was under 50 feet of water and with no sufficient apparatus on hand or within reach to lower the water in the well sufficiently to enable the necessary repairs to be made.

As there was at this time an exceedingly dry season, which had been accompanied by an unusual number of small fires in the town, the situation was truly alarming. The problem then was, how to temporarily check the supply from the new shaft into the pumping well. The first experiment made was by lowering into the drill hole a 4-inch pipe fitted with a tapered wooden plug wrapped with gunny sacks, but this had no material effect on the flow.

Finally the following contrivance was devised. A baloon-shaped bag, in dimensions about 3 feet in diameter and 6 feet long, was made of six plys of bed ticking, roughly quilted into squares. The bag was soaked in linseed oil and a quantity of rye flour inserted and well shaken around. An inch pipe terminating in a sleeve was inserted in the mouth of the bag, which was then securely wired around the pipe. Sewn to the bottom of the bag, was a stout ring, and to this was wired a half pig of iron by a ring bolt inserted into its end. The bag was then wrapped lightly with twine into a cylindrical shape and was lowered into the drill hole in the pumping well by means of sections of pipe, until the weight struck bottom—by

estimation one-half of the bag entering the drift below, the remainder being in the drill hole. The inch pipe was then attached to the service main through a stop cock, and a pressure gauge attached thereto, and the bag was slowly distended until a pressure of 50 pounds per square inch was reached and maintained. The upper part of the bag swelled out and accommodated itself to the irregularities of the drill hole; the lower part of the bag swelled out into a bulb shape, the whole resembling an inverted champagne-bottle cork.

The drainage pump and steam jet were then set to work and speedily emptied the pumping well, the bag being held in shape during the lowering of the water by an interior water pressure of about 10 pounds per square inch in excess of the exterior water pressure. The repairs to the pump having been readily made, the water was exhausted from the bag and the apparatus withdrawn.

In consideration of the fact that factories and supply houses for pumps and other materials, which might have been used in exhausting the water of the pumping well, had such a method been attempted, were at least forty-eight hours distant by express, and that the contrivance described was such as could be constructed out of materials gathered up out of the stock of an ordinary country store and supply room of a blast furnace, and that the total time of stoppage of the pumping engine was about ten hours, including from pumpage to pumpage, it has always impressed me that the treatment of this problem was a most ingenious and clever solution of what threatened to be a most serious condition of affairs for this water-works.

V.

TOPICAL DISCUSSION—THE PROMOTION AND IMPROVEMENT OF RAPID TRANSIT IN PHILADELPHIA.

March 2, 1895.

Mr. William Wharton, Jr.—Gentlemen: I have been requested by our President to make a few introductory remarks on the question of the Promotion and Improvement of Rapid Transit in Philadelphia, and I propose merely to say enough to bring the subject fairly before the meeting, so that a general and free discussion will follow.

There are a number of gentlemen present who have given much attention and thought to this matter, and as it is one about which there are many honest differences of opinion, we should have an interesting and instructive evening.

The success of the elevated railways in New York is due in a very large degree to the narrow width and considerable length of Manhattan Island, by reason of which a large proportion of its population must travel a number of miles up and down between residence and business every day. Even these lines, however, and the radiating lines into Long Island and New Jersey have not the capacity needed, so that a most expensive and thorough system of underground rapid transit has been determined upon in addition, as a matter of imperative necessity. I do not refer to the cable and horse railways of New York as factors in rapid transit in that city, for although immense numbers are carried by them, their passengers are mostly what are termed "short riders."

In Philadelphia the territory occupied by the city is very much more extended and expanded, so that the lines of travel are exceedingly numerous and divergent. Thus the problem of rapidly, safely, comfortably, and cheaply transporting its thirteen or fourteen hundred thousand inhabitants throughout its 129½ square miles of area is invested with new features and attended with complications of its own.

Philadelphia, moreover, has already to some extent rapid transit by means of the suburban trains of the Pennsylvania Rail-

road, Philadelphia, Wilmington & Baltimore Railroad, West Chester Railroad, and Reading Railroad, with their many ramifications and branches. By these, passengers are directly and rapidly brought into the very center and heart of our city, over and through costly bridges, viaducts and tunnels. The service thus given, as a rule, is satisfactory to the patrons of the lines, and has tended immensely to develop the healthy and rapid growth of our suburbs and outlying dependencies, many of which are now joined to the city itself and have become parts of it. Advocates of rapid transit, however, do not admit that these meet the case, saying they are but partial and imperfect exponents of real rapid transit as it should exist. Without entering into that question, there is one point of great significance which has been prominently brought into notice since the introduction of trolley electric railways in Philadelphia, and their extension to so many of our suburbs. This is that the patronage of the local steam railways has in every case where a competing trolley line exists been very extensively and permanently injured by the great numbers preferably using the trolley cars. One cause of this is easily seen; for instance, the fare on the People's Traction Company's cars and the Philadelphia Traction Company's cars from the upper part of Germantown to Philadelphia, and to practically every part of it, is only five cents, while by either of the steam lines the fare is at least three times that amount, and then only to the terminal stations in Philadelphia, from which the passenger must walk to his final destination, or pay five cents more for a street car fare to ride.

Therefore, if we assume that lines for rapid transit ought to be built, can they be made to pay, especially as they could not distribute their passengers throughout the extended area of our city to the numberless places where they want to go? A few desirable routes could probably be selected in Philadelphia for rapid transit lines, but in view of the foregoing, and of their costliness of construction, would they pay? Would capitalists be willing to run that risk? The electric car service in Philadelphia does not meet the requirements of the advocates of rapid transit, but it does so much in that direction, and by its liberal systems of transfers accomplishes so much in gathering

up passengers from all over the city and distributing them almost everywhere they want to go to in the city and its environs, for five cents, that the above questions can most pertinently be asked.

The successful operation of electric motors affords the opportunity of putting up much lighter elevated railways, with ample factors of safety, than would be possible with locomotive steam engines. This, together with the present exceedingly low prices of steel and iron, would permit of the construction of elevated railways at comparatively low figures at this time. With an underground railroad the expense of construction would probably be a fatal objection; and of this, a formidable item would be the necessary interference with, and changes of, sewers, water pipes and other underground constructions. In any event, it appears certain that should any form of rapid transit be established in Philadelphia, electricity will be the motive power used upon it.

The greatest impediment in the way of rapid transit in Philadelphia is that the laws of Pennsylvania, as interpreted by the Courts, are not favorable to the construction or operation of elevated railways for rapid transit in cities of this Commonwealth, and until the present laws are changed, or new laws enacted, there is no probability of any such railway being projected or constructed.

Having thus alluded to some of the prominent features of the subject, I will not take up any more of your time, hoping that a full and lively discussion will ensue.

Mr. A. Langstaff Johnson (Visitor).—In considering this subject for Philadelphia, it will be necessary to determine first, whether rapid transit is wanted, and second, where it can best be put. Philadelphia now compares with New York in its population, but its present facilities for transit are over-crowded. The laws of the Commonwealth should be changed in order to allow overhead construction.

Mr. J. Chester Wilson.—Mr. Widener has been quoted as saying that the projectors of the Northeastern Elevated Railroad are happy since discovering that overhead construction would not have been acceptable in Philadelphia.

Mr. George V. Cresson.—Although the trolleys have made a step toward the solution of this problem, in the busy hours of the day, in some parts of the city, one can hardly get on a car. What we need are overhead roads running northeast and northwest, to accommodate the growing population in those directions. Surface transit is necessarily detained by other street travel, and some different method is, therefore, necessary for rapid transit.

Mr. James Christie.—Rapid transit may be divided into two classes, that by surface roads where a speed of about 8 miles per hour is attained, and by roads above or below the surface, where 15 miles per hour can be easily reached. Many of us can recall that in all of the large cities the introduction of horse-car systems was at first opposed as bitterly as was the introduction of trolley cars at a later date. In New York, for instance, when the old elevated road on Greenwich Street was started, it met with much opposition from the property owners.

Although few cities are now better supplied with surface roads than Philadelphia, we have good service over but very few roads above surface, and they stop at only a few points within city limits. What we need is a system of belt roads running lighter trains at shorter intervals. London already has them underground, but the cars are poorly ventilated and lighted. The Paris roads run nearer the outskirts of the city and are better arranged. The radial systems which we have already, might be supplemented by a belt line running southward, parallel to the Delaware, crossing the lower part of the city and the Schuylkill, and north, around and under Fairmount Park, and eastward to Kensington. With stations about one-fourth mile apart, a speed of 18 miles per hour could easily be attained. There are many reasons in favor of an elevated construction. Its smaller cost, freer ventilation and convenience for travel, would, I think, make it popular with the public.

Mr. Harrison Souder.—Before leaving college, I considered this subject and worked out a "clover leaf" underground plant for rapid transit, the three lobes of the leaf encircling the northern, western and southern parts of the city, and meeting near Broad and Market Streets. In the long run, an underground construction would probably be less expensive, because of its greater permanence.

Mr. Hermann S. Hering.—One of the problems to be met in providing rapid transit, is a division between express and local traffic. For suburban travel, the surface roads are too slow, and this demand should be met by underground or elevated roads. Then, too, it must be remembered that ideal and practical systems are quite different. The city and people must be taken as they are, and work will have to be done slowly.

Mr. George C. Plummer.—In Brooklyn there are four elevated roads running to separate termini. A speed of 20 miles per hour is reached on these, and the electric roads began by attempting to go at the same rate, with many accidents as a result. The elevated roads have been objected to on account of the stairs which must be climbed to reach the platforms.

Mr. Harry B. Hirsh.—We certainly have facilities in Philadelphia from which a good system of rapid transit could be evolved. The Pennsylvania Railroad has made the statement that they did not care for suburban traffic, but I think that before long they will be trying to get back some of the traffic which they have lost by competion with the trolley roads. They and the Reading form trunk lines to the center of the city, and feeder trolley lines could be run from all their different stations.

Mr. John Birkinbine.—In discussing the promotion and improvement of rapid transit in Philadelphia, we must take into account both existing and prospective conditions; for the 129 square miles embraced within the borders of our city is not a square with a side of $11\frac{1}{3}$ miles laid out upon the level floor of a prairie, but it forms an irregular figure extending along the navigable waters of the Delaware River for twenty miles, with topographical features varying from below mean high-tide level to 450 feet above this datum.

The distance on Market Street, from the Delaware River to Cobb's Creek, is five and a half miles—the greatest width of the city, east and west. Broad Street, continued to the city limits, will have a length of nearly twelve miles; but the maximum north and south distance approximates fifteen miles, while the extreme length, between boundaries from southwest to northeast, is about eighteen miles. While a large area is covered by the city of Philadelphia, the business center is not, as in New York,

restricted to a narrow belt between two rivers, and although the exigencies of trade may cause this center to be congested, it is not probable that such congestion will be as great as in our sister metropolis, nor are the avenues of approach restricted mainly to one general direction; hence, any system of rapid transit for Philadelphia must embrace lines of travel to all points of the compass (except possibly east), using the City Hall as a basis. The immediate requirements for rapid transit do not cover the entire area of the city, but any comprehensive plan must take in the whole, and provide for grading abrupt hills, filling ravines, and that portion which is below high water and now protected by dikes must be brought to a level, at least, of city datum (2.75 feet above mean high tide). It is also necessary to take into account the future growth of the city as affecting its area and to allow for an augmented population. The problem is not only to care for the present 1,300,000 people, with numerous additions from near-by points, but for a future growth which may more than double our present number.

Then, too, the favor into which suburban residences have grown makes it essential to embrace in any plan feeders which will reach settlements outside of the city boundaries, for whether these will or will not, at some subsequent date, be incorporated within the municipality, the residents will utilize lines of transportation to the business and other portions of the city.

Rapid transit, within the closely built business part of the city, is impossible with surface roads, for in addition to the interference of vehicles on the streets, the necessity of permitting a nearly continuous line of pedestrians to pass, and the stoppages to take on passengers, there are, within the area bounded by the Delaware and Schuylkill Rivers, South Street and Green Street, no less than 280 crossings or junctions of street railway tracks; and if two crossings are counted for streets on which there are double tracks, there are about 360 such points of danger in the above area. With cars meeting at these points every moment or two, the wonder is that so few, and not so many, collisions occur.

In other portions of the city the interferences and the grade crossings, although less numerous, prohibit any approach at

speeds which come under the modern appreciation of rapid transit without multiplying dangers greatly, and even at the present rate of travel, the chances of accident are numerous. The strain on a motorman is such, that to secure good service, he should receive consideration similar to that accorded to locomotive engineers whose hours of labor are restricted within the bounds of safety, and without such consideration, even limited speed on surface roads is subject to great risks. True, he has not the responsibility of watching his steam and does not, on city roads, approach the rate of speed attained on steam railways, nor does he have, as a rule, as many passengers' lives at stake, although we manage to get a fairly good train load inside a single car often, and in a day's time a motorman may have more people behind him than a locomotive engineer. But the motorman has no switchman to move the switches, no block signal towers to indicate an obstructed track, no clear right of way. The emergencies which he must meet occur every few seconds, and yet he is expected to maintain a good speed.

If we assume that rapid transit by surface roads on street lines is impracticable, we must provide for underground or elevated tracks. Either is practicable, except for a comparatively small portion of the city, but to introduce any comprehensive system, an enormous outlay of money will be demanded.

The rectilinear arrangement of streets in Philadelphia, while giving direct routes to points north and south, east and west, offer but few diagonal avenues for reaching distant points; hence, any system of elevated tracks must either follow the direction of the streets, or occupy valuable property by diagonal routes. This would not, to the same extent, interfere with an underground system, but the cost of construction of the latter would be materially influenced by the necessity of supporting firmly the foundations of buildings, and sustaining without injury sewers, water, gas and other conduits. But in the portion of the city between the rivers, below Callowhill Street, and generally close to the rivers, there would be little space to spare, between the bottom of an underground system high enough to offer good drainage, and a roof which would not interfere with conduits

and sewers now in the streets. An underground system, reeking with city refuse smells, would not be tolerated.

Then, too, underground roads must either come to the surface and be carried as high as the present bridges or be depressed below the bottom of the Schuylkill River where it is crossed. But for a greater portion of the area covered by Philadelphia underground roads could be constructed, with ample drainage, and have cover only restricted in depth by the convenience of reaching stations from the surface level.

Whether elevated or underground systems are used, it will probably be desirable to select routes other than the streets, and if street directions are followed a decided advantage will result from taking routes between street lines, as was done at Chicago.

An underground system would seem to have an advantage in being free from obstructions by snow and sleet, if covered throughout, but if the subway is used with top open, except at street crossings, a drifting snow would find good lodgment. It is, however, probable that the advantages of a subway for 360 days would more than offset this annoyance for say five days in a year.

An underground or depressed system would have the advantage of adding less to the noise of a city than an elevated road, and would prove no obstruction to light or to view. In either system the annoyance of smoke or gases need not follow, for electricity, compressed air or other motive power, will probably be adopted for any rapid transit scheme.

With 150 miles of steam railroad within the city limits, reaching to nearly every part, it would seem possible, by running on circuits, either with steam or electricity as power, to cover a large part of the area (if such traffic could be worked in connection with other business), and thus form the basis of a system of rapid transit which could be materially extended, particularly if operated by a system of transfers with surface street car lines.

Mr. F. Uhlenhaut, Jr.—Within a radius of 2½ miles from the City Hall, the surface roads would seem to offer sufficient accommodations, but trunk lines are needed for travel to points outside this limit.

Mr. William Wharton, Jr.—An unfortunate sentiment exists

in the press and elsewhere, that those who impede the electric cars by unloading freight, are doing something creditable, and I think that something should be done to change this sentiment, and impress the fact that the electric cars are run for the accommodation of the public, as well as for the profit of the companies.

Mr. George V. Cresson.—The police should be instructed to prevent these obstructions, and in a system of rapid transit some provision should be made for light freight traffic across the city.

Mr. George A. Bullock.—As has been remarked, Philadelphia's surface road service is second to none, and I think that before long the increasing population and capital will bring us elevated railroads for more rapid transit.

John C. Trautwine, Jr.—While it is admitted on all hands that the introduction of the trolley system does not furnish a complete solution of the problem of rapid transit in cities, and between cities and their suburbs, it may be claimed that the trolley has, at least, indirectly aided us in seeking such a solution.

In the first place, the trolley is educating the people, including the railroad people, up to the idea of dispatching single vehicles or short trains at short intervals, in the place of long trains at long intervals.

Again, the competition of the trolley, with its lower rates, and with its facility, pointed out by Mr. Wharton, of picking up and setting down passengers near the desired points, will, no doubt, force the elevated and other steam lines to introduce conveniences for which, otherwise, the public might sigh in vain, to say nothing of a reduction in fares.

It has been remarked this evening that in cities like New York, Brooklyn and Chicago, where elevated steam lines and rapidly moving surface lines are in operation side by side, many passengers take the latter in order to avoid climbing the tall stairways to the former, and it would seem probable that the competition of the trolley might, before long, induce the elevated railroads to add elevators at their stations.

The clover-leaf plan, suggested by Mr. Souder, partakes somewhat of the character of the radial and of the belt lines suggested by Mr. Christie, and thus, in a measure, obviates some of the difficulties inherent in each of these systems.

The introduction of electric motors must go far to cheapen the elevated as opposed to the underground railroad, for it would permit the use of a lighter superstructure for the former, while the cost of construction of an underground railway would be practically the same for the lighter vehicles as for the heavier ones which have long been in use.

Mr. Souder's clover-leaf plan would, however, at least in a checker-board city like ours, at once increase the cost of an elevated system, as it would involve cutting diagonally through most of the blocks.

Those who have ridden upon the underground railway in London, are not, unnaturally, opposed to the very name of "underground;" but it should be borne in mind that two of the chief objections to the London system are capable of removal by the introduction of electricity. The first of these is the stifling locomotive smoke with which the tunnel is filled, especially at its summits; and the second is the utterly insufficient lighting by means of one or two feeble oil-lights in the roof of each compartment. The electric-motor would, of course, not foul the air of the tunnel, and the electric light, if introduced upon anything like the scale upon which it is used on some of the streets of this city, would obviate all trouble on that score.

Some one has praised the beneficence and wisdom of Providence in making the great rivers flow past the large cities, and, in listening to Mr. Christie's remarks, it occurred to me that, while we have always regarded the railroad in the same way, that is, as going where the population demanded it, the time may now have come when the railroad should begin to determine the distribution of the population very much as the rivers do, and, so far as the suburban development of cities is concerned, we can see that they have already done so to some extent. With the exception, perhaps, of the old Germantown and Norristown, the railroads leading out of Philadelphia were built in order to connect the city with distant points, and perhaps with little or no idea of developing suburban residence districts. We readily see, however, to what an extent they have been useful in the latter direction, and now our suburban trolley lines parallel these roads and seek to profit by the trade which they have built up.

In New York, as Mr. Wharton has well pointed out, the conformation of the city is such that the location for a projected rapid transit line may be said to have been determined in advance. It *must* run north and south, and the city is so long and narrow that even if there were but a single line, that line would be sure to carry all or nearly all of the long-distance traffic. In other cities, on the contrary, and notably in Philadelphia and in London, the problem, when a rapid transit road came to be built, was where should it be placed? and, whatever the answer might be, a single road, unless it were a belt line, was sure to leave unserved about ninety per cent. of the territory and of its population.

In London, also, one of the chief difficulties with the underground system is, that it is practically of no use to persons desiring to cross from north to south, the district within what is called the inner circle.

It would seem, therefore, that in attempting to relieve the congestion of an overcrowded city, a projected line of rapid transit suburban communication might reverse the usual rule of seeking the population, and boldly place itself where nature had pointed the way, trusting for its future business to its own power of determining the direction of suburban development.

Mr. James Christie.—The matter of locating roads for rapid transit should be placed in the hands of a commission, who could decide where these roads were most needed, and how they should be built.

THOMAS S. R. FLICKWIR.

Thomas S. R. Flickwir, late active member of this club, was born in the city of Philadelphia on the 4th day of September, 1866. He received his early education at the Episcopal Academy of Philadelphia, and entering the University of Pennsylvania in 1882, he was graduated therefrom with the degreees of B. S. and C. E., in 1886.

During the period of his attendance at the University, he gained experience in practical railroad engineering work, with one of the field parties of the Norfolk and Western Railroad Company on preliminary and location surveys and on construction. After receiving his degrees he entered the service of the Norfolk and Western Railroad Company in one of the Engineer Corps of the Cripple Creek Extension.

In the year 1888 he was appointed an assistant engineer on the staff of the Chief Engineer of the Philadelphia and Reading Railroad, and was assigned to duty upon the preliminary and location surveys of the Allentown Terminal Railroad. Upon the completion of this work he was engaged upon various surveys and general work connected with his office, when in 1889 he was placed in charge of the reconstruction and double-tracking of the Philadelphia and Atlantic City Railway, remaining in charge of this work until its completion. Subsequently he was engaged upon the preliminary and location surveys of the Port Reading Railroad.

In the year 1891, Mr. Flickwir accepted the position of Chief Engineer of the Dutchess County Railroad and completed its construction.

In 1893 he again entered the service of the Norfolk and Western Railroad Company as Supervisor of its Radford Division. Resigning this position in the spring of 1894, he was appointed Assistant Engineer of the Special Corps, Bureau of Surveys, City of Philadelphia, and was actively engaged in the duties of this office up to the time of his death, on July 12, 1894.

Mr. Flickwir's many attractive qualities and genial personality drew to him and endeared him to many personal friends.

His sudden death ended a career which gave full promise of continued success and of future distinction in his chosen profession.

SAMUEL LIGHTFOOT SMEDLEY.

Samuel Lightfoot Smedley was born at Edgemont, Delaware County, Pa., December 29, 1832, died at Philadelphia, July 21, 1894. He was a descendant from George Smedley, of Derbyshire, England, who came to America in 1682, with other followers of William Penn, and settled one mile west of the present town of Media, Pa. Here Samuel L. Smedley, the father of Mr. Smedley, was born, but died at the early age of thirty-six, when the subject of our memoir was but two years of age. His education and early training, therefore, devolved upon his mother. As a lad he inherited the mental tastes and strong characteristics of his parents, and developed in his early youth a talent for mathematics. He received his early education at the Friends' Academy, Westtown, Pa., and at a classical school in Germantown. At the age of twenty-one, he came to Philadelphia, where, under the instruction of Joseph Fox, a noted surveyor, he became an expert draughtsman. Being a superior mathematician he made rapid progress as a surveyor and engineer.

In 1856, he plotted the District of West Philadelphia into streets, and soon after published the first complete atlas of Philadelphia, which became the standard for many years. From 1858 to 1872 he was a member of the Board of City Surveyors, and from 1872, until his resignation in 1893, he filled the responsible position of Chief Engineer and Surveyor of Philadelphia.

By reason of his large experience during so long a period, his services were necessarily of great value to the city, which embraces within its corporate limits 129 square miles. The improvements and constructions prosecuted by Mr. Smedley cost many millions of dollars, and, among other works, included the building of the Penrose Ferry bridge; the iron cantilever bridge at Market Street; the Fairmount bridge; the new Walnut Street bridge, the iron work of which is 2,400 feet long; and the Girard Avenue bridge. All these cross the Schuylkill River, but in the list of his constructions are numerous bridges crossing smaller streets, canals and railroads. The Girard Avenue bridge is of iron, is one hundred feet wide, 1,000 feet long, and cost $1,500,000. The city of Philadelphia is intersected by many railroads, in the laying out of which, and in making adjustment to avoid grade crossings in the original locations, Mr. Smedley

acquired a great reputation for proficiency, and by his determination secured a safe and grand entrance to Fairmount Park by tunneling the railroad at Green Street entrance. Largely under his direction, 476 miles of sewers were built, including Cresheim Creek aqueduct, with the extraordinary span of 116-foot stone arch, being next to the largest in this country. He raised the grade of Market Street, west of the Schuylkill; obliterated a valley with steep ascents and descents, and brought the beautiful part of West Philadelphia within easy reach of the center of the city. Mr. Smedley visited the large cities of Europe in 1865, and was forcibly impressed with the value of their public parks. Soon after his return, with other persons he advocated the establishment of a park for Philadelphia. The result was the purchase from the Barings, of England, of 150 acres, known as "Lansdowne," along the Schuylkill. This became the nucleus of the famous Fairmount Park. He made the original surveys; was instrumental in securing George's Hill, with its commanding view of the city; designed and laid out many of the walks and drives, and from 1872 to 1893 was, ex-officio, a member of the Board of Park Commissioners.

During the thirty-five years which Mr. Smedley was connected with the Department of Surveys, he secured and preserved the scattered and rapidly perishing records of the old branches of the city government, a task for which few were better equipped by nature and education than himself, and a labor congenial to one of antiquarian tastes. To his diligence and care the city owes it that the Bureau of Surveys to-day is rich in valuable books, papers, plans and records.

Mr. Smedley, in addition to being a member of the Engineers' Club of Philadelphia, was also a member of the American Society of Civil Engineers, a member of the Historical Society of Pennsylvania, and its recording secretary for fourteen years. He was also a member of the Antiquarian Society, Academy of Natural Sciences, Franklin Institute, West Philadelphia Institute, Delaware County Institute of Science, the Union League of Philadelphia and the American Public Health Association.

It is much to have passed thirty-five years as a public official, and to leave behind a character for ability, integrity, sincerity and kindness, such as remains attached to the name of Samuel L. Smedley.

NOTES AND COMMUNICATIONS.

THE PROPER FORM OF RAIL FOR STREET RAILWAYS.

Contributed by Mr. Wilfred Lewis, *at Meeting of February* 2, 1895.

The rail tread now generally in use, and still extending in all directions, was originally designed for horse cars when cobblestone pavements were the penalty for turning off the track. Then it was desirable that the rail should be of such form as to keep a wagon from running off, because the pavements were universally bad and travel was not impeded by vehicles moving at about the same rate as the cars.

Now we have pavements just as good as a rail to drive on, and better in fact, because there can be no side strain on the wheels as the horse swerves from side to side, cars moving at railroad speed and the same old rail tread, which catches and holds everything that attempts to escape. The track is practically useless for driving purposes, because a vehicle no sooner starts than it is obliged to turn out for the next car, and in order to turn out the horse must be brought to a walk and pulled around almost square before the front wheels will mount the sides of the rails. Thus, the transit of passengers is continually delayed, driving through the streets is tedious, difficult and dangerous, and as an insult to the injury imposed upon the public by the use of such a rail, we have an ordinance that teams must not delay the progress of trolley cars. The grooved rail on some of our street crossings, and quite generally used in other cities, would avoid all this trouble.

Is it not within the province of the Engineers' Club to express itself strongly on this subject and exert its influence to have a decent rail adopted for use in this city?

DISCUSSION.

Mr. Wm. Wharton, Jr.—The question, as stated by Mr. Lewis, has been argued by the public for many years, the trouble being that everybody having a vehicle to pull expects to use the rails, and consequently loads it with about twice as much as it can well draw upon a street pavement. There are many objections to the grooved rail. If the groove is made wide, the wheels of light carriages get into it and are badly wrenched in turning out, while, if the groove is narrow, it soon becomes filled with dirt, and in winter, with snow and ice. In New York City they even found it difficult to keep the cars on the track from the latter cause. Personally, I believe that the Philadelphia tramway is the best for all concerned. Two years ago, when a certain road in Baltimore was to be extended, the grooved rail was used on the new part with the result that ruts were soon worn on both sides of the rails, and vehicles were constantly catching in them.

HIGHEST WIND VELOCITIES, AS GIVEN BY THE U. S. WEATHER BUREAU, FROM 1872 TO 1894, AT P. O. BUILDING, PHILADELPHIA.

Contributed by Mr. E. F. Miller, *at Meeting of February* 16, 1895.

TABLE.

Highest velocity in the month of	Occurred in the years of	Velocity recorded by anemometer. M.P.H.	Corrected velocity, as per table. M. P. H.	Corresponding pressure per square foot.
January	1878 and 1885	52	42.2	7.13 lbs.
February	1876, 1880, 1886	48	39.3	6.18 "
March	1888	60	48	9.22 "
April	1879	50	40.8	6.67 "
May	1889	60	48	9.22 "
June	1889	46	37.8	5.72 "
July	1876	40	33.3	4.44 "
August	1893	55	44 4	7.89 "
September	1889	54	43.7	7.64 "
October	1876	75	58.7	13.74 "
November	1873	66	52.3	10.94 "
December	1876	63	50.2	10.08 "

Equation, $P = .004\ SV^2$ (as used by U. S. Weather Bureau).

P=Pressure per square foot, in pounds.

S=Surface in square feet.

V=Corrected velocity of wind, in miles per hour.

The table for correcting anemometer readings, in use by the Weather Bureau, is found in Professor Marvin's article in *Engineering News*, December 13, 1890, also in annual report of Chief Signal Officer, 1890.

DISCUSSION.

Prof. Edgar Marburg.—Observations on the effects of high wind pressures and experiments—notably those made at the Firth-of-Forth bridge—have shown conclusively that the area upon which the maximum intensity of pressure is exerted at any one period is usually a very restricted one. This circumstance has an immediate and a very important bearing on the question of the stability of bridges and buildings under wind pressures. The mean intensity of pressure on the exposed walls of a lofty business block is undoubtedly greatly less than the maximum intensity of pressure existing simultaneously upon a limited portion of the surface in question, even though the force of the wind were entirely unbroken by other buildings in that vicinity.

Mr. F. Schumann.—This question of wind pressure must certainly be considered by any engineer who wishes to design a structure with maximum strength and minimum quantity of materials. When the Tay bridge blew down, the pressure was fifty-six pounds per square foot, and I do not think it would be safe to calculate on less than fifty pounds. (Mr. Schuman describes two instances that had come under his notice

in one of which an 8-inch yellow pine pole was snapped off, and in the other a 22-inch oak tree twisted across the trunk by the pressure of the wind.)

MR. CLAYTON W. PIKE.—Experiments made by Lieutenant Crosby seem to indicate that the pressure of wind varies as the first, rather than the second power of the velocity.

A SYSTEM OF NOTATION FOR PLANS OF WATER SUPPLY AND SEWERAGE SYSTEMS.

Contributed by MR. W. H. DECHANT, *at Meeting of March* 16, 1895.

DURING last year we were called upon to make plans of the water supply systems of the City of Reading, Pa., including the service-pipes in the streets. To show the different size pipes definitely, graphically, and in a simple form, so that the size of any pipe could be seen at any point, we originated a plan which, as far as we know, was not used before and which has given us very satisfactory results.

The sizes of the pipes in streets ranged from 4 to 24 inches.

Taking the size of pipes in inches, and assuming the inches as representing feet, we drew broken lines, the blocks or dashes of which were drawn to scale five times the diameter of the pipes in length by the diameter of the pipe in width.

For example:

For a 24-inch pipe, we made the dashes to scale, 120 feet long by 24 feet wide.
" 10 " " " " 50 " " 10 "

The spaces between these dashes were made equal to the length of the dashes, and in these spaces were marked in Roman numerals the size of pipe.

The advantages of this plan are:

(1) Looking at the whole map or plan, the various sizes of pipe are presented graphically, showing at once the location of the large and small pipes.

(2) The marking of the size all along the length at close intervals is very important where the sizes frequently change and enables the size to be seen at once without any reference to color or a following of the line to find a size mark.

(3) The pipe lines thus made are also peculiar and distinctive, making them easy to follow among the other lines on plans.

The plans we made were to a scale of 200 feet to an inch; these were reduced by photo-lithography so as to make them nearly 1,000 feet to an inch; even at this scale the sizes of pipes can be read with the naked eye.

ANNUAL REPORT OF THE BOARD OF DIRECTORS.

For the Fiscal Year 1894.

Presented at the Annual Meeting, January 19, 1895.

To The Engineers' Club of Philadelphia,
1122 Girard Street.

Gentlemen:—In compliance with the requirements of the By-Laws, the Board of Directors beg to offer the following statement of the affairs of the Club for the year ending December 31, 1894.

During the year there have been eighteen regular meetings of the Club, at which there was an average attendance of seventy-four, the maximum attendance being one hundred and eighteen and the minimum forty-eight. A comparison of this statement of attendance with the similar one presented in the Annual Report for 1893, is of interest. During 1893 the average attendance was forty-six; the maximum attendance being sixty-eight and the minimum thirty-two.

The Board desires to call the attention of the Club to the success attending last year's increase of the Club dues. For several years the evidence was clear,—that either dues must be increased, or the Club must settle down to a humble form of existence, with decreased Club facilities. Several successive "Boards" had wrestled with this problem and had seen no other solution. The fear was entertained by many that increase of dues would be followed by a decrease of membership. Notwithstanding the financial stress of the past two years, the Club now stands with but slightly decreased membership, and is financially stronger than ever before. There is no doubt that the cash in Sinking Fund will be ample to meet the Club's notes when they fall due. With the notes paid off, the Club will be practically free from debt, and able to devote a larger proportion of the dues than heretofore to increasing the attractiveness of the Club. There has been a strong feeling amongst members of the Club that the "social features" should be extended, and the Board would suggest that, with the Club's improved financial condition, some share of the funds can probably be devoted to the encouragement of this side of our Club life.

The Board has made a careful analysis of the accounts of the Treasurer, and finds that the actual amount of money received from dues, initiation fees, advertisements, and all other sources which could be called legitimate sources of income for the year 1894 amounted to	$5828 20
The actual cash expenditure made during the year	5752 67
Thus making the cash gain for the year.....	$75 53
A careful estimate on the same basis, of the probable income during the year 1895, shows the probable amount available to be	$5855 00

A reasonable estimate of the actual cost of running the Club, curtailing none of the privileges of members, but allowing of no unusual expenditures, is	$4840 00
Adding to this the balance of the amount, which must be set aside as a sinking fund	465 53
Will make a total outgo	$5305 53

This leaves an approximate balance for extraordinary expenses of $549.47.

The Board adds to this report as an appendix, a statement showing clearly how these figures are reached.

The condition of the Club at the end of the year, crossing off all bad and probably bad accounts, shows that the good money assets of the Club amounted to $1479.64.

The total liabilities of the Club, including every known account against the Club, amounted to $2105.08.

Leaving an actual deficit at the end of the year of $625.44, as against a deficit of $1693.80, at this time last year, a reduction during the year of $1068.36 of outstanding liabilities.

During the year a number of minor improvements have been made to the Club house. In October the Welsbach Incandescent Gas Light Company presented thirty-six burners to the Club, and mounted them on chandeliers in various parts of the house. This valuable gift has been highly appreciated by those who have visited the house since the introduction of the new lights.

The use of the Club house was tendered to the American Institute of Electrical Engineers during their Annual Meeting in Philadelphia, and a reception was given to the Institute by a Committee representing the Electrical Section of the Franklin Institute and the Engineers' Club.

An excursion to Reading was made in June, in which a party of forty, including eight ladies, participated. Most of the arrangements were perfected by a local committee, consisting of members of the Club and citizens of Reading. The programme, which had been arranged, was very closely carried out, which resulted in a very pleasant visit.

During the year the Board has held fifteen meetings, ten regular and five special, and it is highly gratifying to know that at no meeting was the Board without a quorum.

The Publication Committee during the year issued four numbers of the PROCEEDINGS, and each number has been issued on time.

The question of allowing papers to be printed in advance of their appearing in our PROCEEDINGS has been discussed, and the Committee has adopted a rule forbidding such publication.

The Committee has succeeded in getting the PROCEEDINGS admitted at the Philadelphia Post Office at second-class rates. This result is a large saving to the Club in the matter of postage.

Some changes in the time of issuing the PROCEEDINGS, and also in the numbers constituting a volume, and the reasons for making these changes, are as follows:

By the arrangement heretofore existing for issuing the PROCEEDINGS in January, April, July and October, it has been impossible to get material for the October num-

ber without reserving papers read prior to the summer vacation. This plan puts a prize upon the delay of papers. In order to obviate this delay the Committee deemed it best to change the date of the October number to November, and to adopt the following arrangements for the material to be issued in each number of the PROCEEDINGS:

April: Complete proceedings for months of January, February and March.

July: Complete proceedings for months of April, May and June.

November: Complete proceedings for months of July, August, September and October.

January: Complete proceedings for months of November and December.

By the term "complete proceedings" is meant all papers read, Minutes of the Club and Board of Directors, Contributions to Library, Memorials, etc. The following out of this plan ought to insure keeping the PROCEEDINGS up to date.

The volumes will, with the above arrangements of the numbers, begin with the April number, and thus each volume will contain the entire proceedings of the Club for a calendar year.

The above changes cause the statement of the actual cost of PROCEEDINGS for the past year to be too large by about $90.00, since the numbers published contain the proceedings for thirteen instead of twelve months.

The Report of the Trustees of the Sinking Fund is as follows:

	Cash, Dr.	Cash, Cr.
To receipts from Club dues	$934 47	
By cash paid dividend		$350 00
By cash for redemption of notes		300 00
By balance on hand		284 47
	$934 47	$934 47

The office has record of the deaths of the following members of the Club during the year:

Spencer C. McCorkle, deceased March 20, 1894.
Thomas S. R. Flickwir, deceased July 12, 1894.
Samuel L. Smedley, deceased July 21, 1894.
Henry W. Dunne, deceased August 26, 1894.

The additions to the membership have been thirty-eight Active and three Associate, making a total of forty-one. Nineteen Active members and one Associate were stricken from the rolls December 31, 1894, according to the By-Laws. The number of resignations during the year was thirty-four Active and three Associate, making a total of thirty-seven.

The following tables show the number of members in the Club on December 31, 1894:

	Resident.	Non-resident.	Total.
Honorary	0	1	1
Active	275	140	415
Associate	13	3	16
	288	144	432

The following is an analysis of the column of totals:

	Honorary.	Active.	Associate.
Roll December 31, 1893	1	434	17
Additions		38	3
		472	20
Deceased		4	
		468	
Resignations		34	3
		434	17
Dropped for two years' indebtedness		19	1
Roll December 31, 1894	1	415	16

A comparison with the record of last year will show that the number of resident members has increased by four, and the number of non-resident members decreased by twenty-four.

The Information Committee provided during the year a highly interesting series of papers and discussions. The list appended gives the principal papers read at different meetings during the year:

JANUARY 6.—The Engineering Problem of Irrigating Large Areas. By Major J. W. Powell.

JANUARY 20.—Annual Report of the Board of Directors. Annual Report of the Treasurer. Annual Address of Retiring President.

FEBRUARY 3.—The Magnetic Concentration of Iron Ores. By Edward K. Landis.

FEBRUARY 17.—The New Falls of Schuylkill Bridge of the Philadelphia and Reading Railroad Company. By W. B. Riegner. An Hydraulic Problem. By John C. Trautwine, Jr. Memorial of Joseph D. Potts.

MARCH 3.—Comments on Current Practice in the Designing of Plate Girders. By Prof. Edgar Marburg. The Old Viaduct Bridge over the Conemaugh. By J. Chester Wilson.

MARCH 17.—Discussion on Iron and Steel. By J. S. Robeson. Some Results Obtained in the Government Investigation of American Timbers. By Edwin R. Keller. The New Building Law of the City of Philadelphia. By Frederick H. Lewis.

APRIL 7.—The Baptism of the Great Niagara Tunnel. By Emile Geyelin.

APRIL 21.—The First United States Pneumatic Postal System. By A. Falkenau.

MAY 5.—Rainfall and Floods. General Discussion. The Electro-Metallurgy of Gold and Silver. By A. L. Eltonhead.

MAY 19.—Notes on the Improvement of the Delaware River at Philadelphia. By L. Y. Schermerhorn.

JUNE 2.—Rebuilding the Pennsylvania Railroad after the June Flood, 1889. By Joseph T. Richards. The Quadricycle Peugeot. By A. E. Lehman.

JUNE 16.—The Engineering Features of the Harrison Building. By W. C. Furber. Discussion on the Improvement of the Delaware River at Philadelphia. By Benjamin Franklin.

OCTOBER 6.—Memorial of Thomas M. Cleemann. Atmospheric Resistances. By Prof. Walter L. Webb.

October 20.—Unit Stresses for Railroad Bridges of Wrought Iron. By Prof. Silas G. Comfort. The Electro-Metallurgy of Gold and Silver. By A. L. Eltonhead.

November 3.—The Filtration of Public Water Supplies. By Dr. Henry Leffmann.

November 17.—Highway Improvements in Philadelphia. By George A. Bullock.

December 1.—Memorial of Henry W. Dunne. Specifications for Portland Cements and for Cement Mortars. By Frederick H. Lewis.

December 15.—Boiler Explosions. By John L. Gill, Jr. The Principles of Calculus in a new Light. By Carl G. Barth.

APPENDIX.

	Apparent Income for 1894.	Actual Receipts in 1894.	Crossed Off Books in 1894.	Apparent Income for 1895.	Estimated Receipts in 1895.
DUES.					
1891 Dues.					
Due January 1, 1894	$ 92 50				
Crossed off books			$ 92 50		
1892 Dues.					
Due January 1, 1894	170 00				
Paid		$ 15 00			
Crossed off books			$155 00		
1893 Dues.					
Due January 1, 1894	425 00				
Paid		175 00			
Crossed off books			250 00		
1894 Dues.					
Billed January 1, 1894	5085 00				
New members	615 00				
1894 dues prepaid			14 83		
Paid		4577 50			
Crossed off books			555 00		
Unpaid				$552 67	$300 00
1895 Dues.					
Billed January 1, 1895				4955 00	4700 00
Paid in advance.	25 00	25 00			
ADVERTISEMENTS.					
Due previous to 1891	80 00				
Crossed off books			80 00		
Due from 1891	76 00				
Crossed off books			40 00		
Unpaid				36 00	
Due from 1892	78 00				
Crossed off books			20 00		
Unpaid				58 00	
Due from 1893	115 00				
Paid		69 00			
Unpaid				46 00	10 00
Billed in 1894	909 00				
Paid		641 27			
Crossed off books			105 73		
Unpaid				162 00	75 00
Billed for 1895, four months				750 00	700 00
PROCEEDINGS AND REPRINTS.					
Due January 1, 1894	43 95				
Additional sales in 1894	154 45				
Paid		140 50			
Unpaid				50 00	20 00
Crossed off books			7 90		
1895 sales				50 00	50 00
Rec'pts from other sources	184 93	184 93			
	$8053 83	$5828 20	$1320 96	$6659 27	$5855 00

	Estimate for 1894.	Expenditures for 1894.	Estimate for 1895.
Salaries	$ 1065 00	$ 1052 50	$ 1105 00
Proceedings	1000 00	1092 06	1000 00
House	1500 00	1371 29	1400 00
Luncheons	450 00	563 00	550 00
Notices	300 00	439 39	425 00
Secretary's Office	360 00	222 99	225 00
Treasurer's Office	15 00	11 36	15 00
Library	15 00	30 43	30 00
Information Committee	45 00	73 35	75 00
Sinking Fund	960 00	883 50	465 53
Miscellaneous	15 00	12 30	15 00
	$5725 00	$5752 67	$5305 53

GOOD ASSETS.

December 31, 1894.

Cash Balance	$140 17
Dues, 1894	300 00
Advertisements, 1893	10 00
" 1894	75 00
Due on small accounts	20 00
Sinking Fund	934 47
	$1479 64

LIABILITIES.

December 31, 1894.

Prepaid dues	$25 00
M. R. Mucklé, Jr., & Co.	5 00
John C. Trautwine, Jr.	27 66
Globe Printing House	256 56
Bills Payable	1400 00
Henry Veit	50 00
Sherman & Co.	26 40
Electro-Phototype Co.	24 61
C. T. Milligan	3 10
W. C. Kirk & Co.	10 75
Prepaid subscription	1 00
Rent	275 00
	$2105 08

Excess of liabilities over assets, December 31, 1893	$1693 80
" " " " 1894	625 44
Decrease of indebtedness during 1894	$1068 36

PUBLICATION COMMITTEE.

PROCEEDINGS 1894.

Expenditures.

Printing XI.—1	$96 66
" " —2	224 84
" " —3	193 67
" " —4	151 53
Reprints	51 00
Illustrations	136 89
Postage	89 48
Wrappers	12 00
Sundries	13 92
	$969 99

Receipts.

Adv. XI.—1	$159 00
" —2	184 00
" —3	207 00
" —4	186 00
Subscriptions	34 00
Sales	120 45
Reprints	56 00
	$946 45

Loss on PROCEEDINGS, $23.54.

ANNUAL REPORT OF THE TREASURER.

For the Fiscal Year 1894.

Presented at the Annual Meeting, January 19, 1895.

To The Engineers' Club of Philadelphia.

Gentlemen:—The Treasurer submits the following report:

Receipts—Cash.

Dues and Initiation Fees:		
1892	$ 15 00	
1893	175 00	
1894	4577 50	
1895	25 00	$4792 50
Advertisements:		
1893	$184 00	
1894	526 27	710 27
Proceedings:		
1893	$ 6 20	
1894	80 80	87 00
Reprints:		
1893	$ 6 00	
1894	47 50	53 50
Chicago Fund:		
Returned	$ 85 00	
Trustees	49 50	134 50
American Inst. Elec. Engs.		24 50
Reception Committee		2 75
Interest on Deposits		9 92
Exchange		01
Notices		1 50
Keys		11 75
Total income		$5828 20
Cash balance Dec. 31, 1893		64 64
		$5892 84

Expenditures—Cash.

Salaries:		
Secretary	$200 00	
Treasurer	25 00	
Clerk	587 50	
Janitor	240 00	$1052 50
House:		
Rent	1100 00	
Coal	73 75	
Gas	55 80	
Ice	18 25	
Repairs and supplies	123 49	1371 29
Secretary's Office:		
Stamped envelopes	93 00	
Letter heads and stationery	63 00	
Postage and supplies	66 99	222 99
Proceedings		1092 06
Notices, records, etc.		439 39
Treasurer's Office		11 36
Information Committee		51 95
Periodicals for Library		30 43
Gas for lantern		21 40
Luncheons		563 00
Sinking Fund		883 50
Sundries		12 80
Total Disbursements		$5752 67
Cash Balance Dec. 31, 1894		140 17
		$5892 84

Respectfully submitted,

Geo. T. Gwilliam,
Treasurer.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, January 6, 1894.—President John C. Trautwine, Jr., in the chair. Sixty-seven members and visitors present.

The Tellers reported that, at the election held this date, the following gentlemen were elected to Active Membership: Messrs. Victor Angerer, John A. Carlisle, Ernest Hayward Fairbanks, George B. Hartley, Harrison W. Latta, Norman Leslie Stamm, Alfred G. Stokes, George B. Taylor, and Edward R. Zoll.

Resignations from active membership were presented and accepted from Messrs. Thomas L. Lüders, Jr., C. R. Claghorn, W. G. Wallbridge, S. P. Mitchell, W. W. Coe, Preston B. Lee, Thomas Willis Fleming, David W. Flickwir, T. Kennard Thomson, John T. Boyd, Charles E. Ross, and James D. Moffet. The resignation of Mr. J. Walter Douglass from Associate Membership was also presented and accepted.

The Secretary announced that the Board of Directors had appointed as auditors, Messrs. Max Livingston, H. C. Lüders, and Henry G. Morris, with Messrs. Gratz Mordecai, and John S. Mucklé, as alternates; and as tellers for 1895, Messrs. John T. Loomis, C. H. Ott, and G. Bacon Price, with Messrs. George M. Sinclair, and S. S. Evans as alternates.

Mr. A. Falkenau announced that Mr. Wilfred Lewis had asked him to bring before the Club for consideration the question of the proper form of rail to be used on street railways. His communication on this subject was laid on the table, to be brought up at a future meeting.

Hon. Charles D. Walcott, Director of the United States Geological Survey, presented a paper on "The United States Geological Survey and Its Methods of Work." The address was profusely illustrated by lantern reproductions, topographic and geologic maps, photographic views of equipments and instruments used in the work, and of places in the West showing peculiar characteristics. An oral discussion followed, participated in by Messrs. Birkinbine, Dahlgren and others, and at its close a resolution of thanks was tendered to Director Walcott.

Annual Meeting, January 19, 1895.—President John C. Trautwine, Jr., in the chair. Ninety-seven members and visitors present.

Resignations of Active Membership were presented and accepted from Messrs. Henry S. Munroe, Alan Wood, Jr., James M. Stewart, and Henry Millholland.

Mr. John C. Trautwine, Jr., the retiring President, delivered the annual address, the subject chosen being, "Engineering Progress in Philadelphia, during 1894."

Mr. Trautwine's remarks were illustrated by maps and photographs displayed by the lantern.

Professor Silas G. Comfort read the annual report of the Board of Directors, and the Secretary read the annual report of the Treasurer, in the absence of that officer, substantially as they were printed and sent out in advance of the meeting.

Upon motion these reports were adopted.

In discussion upon them, Mr. John L. Gill, Jr., Chairman of the Finance Committee, stated that since January 1st the Club had received approximately $1,800, and that after deducting the 20 per cent. for the Sinking Fund, and paying off all out-

standing indebtedness, the Club will be able to wipe out the loan secured by two-year notes, and leave a balance of about $800 in the Treasury.

This statement of the Club's financial standing was received with applause.

The Tellers reported that at the election held this date, 108 legal votes had been cast, and the following candidates were declared elected: President, George S. Webster; Vice-President, John L. Gill, Jr.; Secretary, L. F. Rondinella; Treasurer, George T. Gwilliam; Directors, W. C. Furber, Henry Leffmann, Edgar Marburg.

Mr. George S. Webster, President-elect, was introduced by the retiring President and, after appropriate thanks, made some remarks on the present standing and future prospects of the Club, and of the part that it should play in advancing the status of the engineering profession.

Regular Meeting, February 2, 1895.—President George S. Webster, in the chair. Sixty-five members and visitors present.

The Secretary reported the death of Mr. Clement Lodge, Active Member, and, upon motion, the chair was requested to appoint a committee to prepare a suitable memorial.

Mr. V. Angerer read a paper on "Investigation and Experiments for the Determination of the Groove in Guard Rails for Street Railways."

Mr. Wilfred Lewis sent a written discussion, and an oral discussion followed, participated in by Messrs. James Christie, A. Langstaff Johnston, William Wharton, Jr., and Captain Edward B. Ives.

Business Meeting, February 16, 1895.—President George S. Webster in the chair. Fifty-nine members and visitors present.

The Tellers reported that at the election held on this date, Messrs. F. Macomb Cresson, Walter Frick, John P. P. Lathrop, Samuel B. Locke, Nelson Macy, Austin P. Mathews, George S. Perkins, and Edwin C. Wolff were elected to Active Membership, and Mr. Louis Jay Gerson to Associate Membership.

Resignations of Active Membership were presented and accepted from Messrs. Frank Cooper, F. R. Brown and Jerome T. Kelly.

The Trustees of the sinking fund presented their final report, showing that the percentages of monthly income from dues had been paid to them from December 8, 1893, to January 26, 1895, amounting to $1,400, and that this amount had been repaid in full to the holders of the Club's notes between March 29, 1894, and February 5, 1895.

Upon motion the report was accepted and the trustees discharged with the thanks of the Club for their successful management of this fund.

The Special Committee appointed for this purpose presented a memorial of Thomas S. R. Flickwir.

A recommendation from the Board of Directors, that the meetings of the Club be closed as near 10 P.M., as possible, was very thoroughly discussed, and upon motion it was resolved that the Club endorse this recommendation of the Board.

The Secretary read a communication from Prof. Silas G. Comfort, resigning his position on the Board of Directors, on account of increase of professional work, which would prevent his giving the amount of attention that is due from a member of the Board to the interests of the Club.

Upon motion, the resignation was accepted, and the thanks of the Club were tendered

to Professor Comfort for his untiring and intelligent devotion to the work of the Board of Directors in general and to that of the Publication Committee in particular.

The Secretary reported the receipt of a colored lithograph, suitably framed, showing the proposed work in the depression of tracks of the Reading Railroad between Pennsylvania Avenue and Noble Street, from Mr. George S. Webster, and, upon motion, the thanks of the Club were tendered to Mr. Webster for this gift.

Mr. R. L. Humphreys brought up the question of having a stenographer to take down verbatum the discussions at the Club meetings, so that an accurate record of what was said on the floor might be obtained for the PROCEEDINGS instead of a sometimes very different account afterwards written up by the author of each discussion. This was very fully commented upon, the question of expense being considered, and the matter was finally referred to the Board of Directors.

Mr. C. L. Prince, as Chairman of the House Committee, asked for the sense of the meeting as to the propriety of smoking during the meetings. In the discussion which followed the general feeling seemed to be, that, if smoking annoyed any member at the meetings, it should be discontinued.

Mr. C. H. Ott read a paper on "A Problem in Hydrostatics and its Ingenious Solution."

Mr. E. F. Miller presented a communication on " Highest Wind Velocities as Given by the U. S. Weather Bureau, from 1872 to 1894, at P. O. Building, Philadelphia," which was discussed orally by Prof. Edgar Marburg, Messrs. F. Schumann and Clayton W. Pike.

REGULAR MEETING, MARCH 2, 1895.—President George S. Webster in the chair. Seventy-two members and visitors present.

A topical discussion followed on "The Promotion and Improvement of Rapid Transit in Philadelphia," which was participated in by Messrs. Wm. Wharton, Jr., A. Langstaff Johnston, J. Chester Wilson, George V. Cresson, James Christie, Harrison Souder, Hermann S. Hering, George C. Plummer, Harry B. Hirsh, John Birkinbine, F. Uhlenhaut, Jr., George A. Bullock and John C. Trautwine, Jr.

BUSINESS MEETING, MARCH 16, 1895.—Vice-President A. Falkenau in the chair. Forty-seven members and visitors present.

The Secretary read a communication from the Secretary of the American Society of Mechanical Engineers, accompanying a report from its Committee on Standand Gauges, in which the Committee deprecate earnestly " the use of any of the numerous wire and sheet metal or other trade gauges now in vogue, and strongly urge the use of thousandths of an inch for all kinds and classes of small measurements." Upon the request of the American Society, the Chair was directed to appoint a Committee to co-operate in this matter.

A communication from M. William H. Dechant was read, in which he described " A Method of Notation for Plans of Water Supply and Sewerage Systems."

The committee appointed for this purpose presented a memorial of Samuel Lightfoot Smedley.

The Tellers reported that Messrs. James A. Brown, George W. Hayes, Marian R. Rodgers, Fritz Uhlenhaut, Jr., and Theodore Voorhees had been elected Active Members of the Club, and that Mr. Charles B. Souder had been elected to Associate Membership.

Captain C. B. Dahlgren gave a very interesting description of his experience in Mexico, twenty-five years ago, in charge of the Nuestra Senora de Candelaria mine, illustrating his remarks with a collection of miners' implements and clothing.

At the conclusion of his remarks, Captain Dahlgren answered some questions relating to the differences in method between Mexican and American mining.

Mr. Harrison Souder exhibited a series of photographs of the silver sections of Mexico, which further illlustrated the subject of Captain Dahlgren's remarks.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, January 5, 1895.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors W. B. Riegner, Henry J. Hartley, John L. Gill, Jr., Edward K. Landis, Silas G. Comfort, Charles L. Prince, the Secretary and the Treasurer.

Professor Comfort, as Chairman of the Special Committee, appointed at the Board's last meeting, presented a draft of the Annual Report. This was accepted for presentation to the Club at its annual meeting, and Professor Comfort was authorized to read it at that time, with any verbal explanations that he considered necessary.

The Treasurer also presented a draft of his Annual Report, which was ordered to be printed with that of the Board, and brought up for action at the Annual Meeting.

Regular Meeting, January 19, 1895.—Present: Vice-Presidents James Christie and A. Falkenau, Directors W. B. Riegner, John L. Gill, Jr., Edward K. Landis, Silas G. Comfort, Charles L. Prince, the Secretary and the Treasurer.

The Treasurer's report showed:

Balance from November	$81 52	
Amount received during December	461 75	
		$543 27
Amount expended during December		403 10
Balance December 31, 1894		$140 17

The Finance Committee reported that at this date there was in the Treasury $1,902.92, and that after the percentage had been paid from this into the Sinking Fund, that fund would amount to $708.97, which was within $41.03 of the total amount needed to pay off all of the two-year notes. Mr. Gill therefore moved that the Finance Committee be authorized to order paid into the Sinking Fund the amount necessary to pay off all of the Club notes. Professor Comfort opposed the motion on the ground that the original provision was that 20 per cent. be set aside from the income from dues for this purpose, and he considered an extra payment irregular. After discussion in favor of the motion by other members, it was put and carried.

The Membership Committee reported three applications for membership now on file.

Mr. Christie called the attention of the Board to the fact that he still held in trust the fire insurance policy of the Club House, and upon motion the Secretary was instructed to rent a safe deposit box of the Girard Trust Company, in which this and other Club papers of value might be placed.

The question was brought up and discussed as to the advisability of the Treasurer furnishing surety, and upon motion he was instructed to ascertain the cost of a bond for $2,000.

It was moved and carried that a suggestion be made to the incoming Board to establish a permanent Sinking Fund, by setting aside the initiation fees or some proportion of the income.

Organization Meeting, January 26, 1895.—Present: President George S. Webster, Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Edward K.

Landis, Charles L. Prince, Silas G. Comfort, W. C. Furber, Henry Leffmann, Edgar Marburg, the Secretary and the Treasurer.

The President appointed the following standing Committees for the year 1895, the first named in each case being Chairman:

Finance.—Messrs. Gill, Landis, and Prince.

Membership.—Messrs. Landis, Leffman, and Falkenau.

Publication.—Messrs. Marburg, Gill, and Leffmann.

Library.—Messrs. Comfort, Furber, and Marburg.

House.—Messrs. Prince, Furber, and Leffmann.

Information.—Messrs. Falkenau, Prince, and Comfort.

Mr. Gill suggested that the meetings of the Board and of the Club should be called to order as promptly as possible, and that the Club meetings be closed at a stated time. It was moved that the Board recommend at the next Business Meeting, that in future the meetings of the Club be closed as near 10 P.M. as possible. Carried.

Mr. Gwilliam reported that our fellow-member, Clement Lodge, had died during the past week, and promised to furnish the office with particulars to report to the Club.

Upon motion, the Club meeting of February 16th, was ordered to be a Business Meeting for membership elections, resignations, etc.

Mr. Gwilliam suggested that the House Committee recommend to the Club that there be no smoking at the meetings.

REGULAR MEETING, FEBRUARY 16, 1895.—Present: President George S. Webster, Vice-Presidents [A. Falkenau] and John L. Gill, Jr., Directors Edward K. Landis, Silas G. Comfort, Charles L. Prince, Edgar Marburg, Henry Leffmann, W. C. Furber, the Secretary and the Treasurer.

The Treasurer's monthly report showed:

Balance from December	$ 140 17	
Amount received during January	2,009 75	
		$2,149 92
Amount expended during January		1,237 70
Balance January 31, 1895		$912 22

The Treasurer also reported that the American Surety Company would go his bond for one per cent. of its face value, or probably less, if checks were countersigned by some other officer. Upon motion it was ordered that the proper officers arrange for a bond of $2,000 at a cost of not more than $25 per year.

A motion that arrangements be made to have the checks countersigned by the President, or Chairman of the Finance Committee, was discussed, and afterward referred to the latter Committee and the Treasurer for action.

The Secretary read the resignations of Messrs. F. R. Brown, Jerome T. Kelly and Frank Cooper, which were ordered to be presented at the Club meeting of this date.

The final report of the Sinking Fund of the Club was read and ordered to be presented at the Club Meeting of this date.

The Finance Committee reported bills approved and ordered paid amounting to $382.43

The Secretary reported that, in accordance with instructions, he had rented safe deposit box No. 209 in the Girard Life Insurance Annuity and Trust Company, for

one year from February 4, 1895, and, at his request, the Treasurer was authorized to hold the second pair of keys.

Mr. Landis moved that a telephone be rented for the use of the office and members of the Club. The question of expense was thoroughly discussed, and the motion, upon being put, was lost.

Prof. Comfort stated that other professional duties would prevent his giving sufficient time and attention as a member of the Board, and he therefore felt obliged to resent his resignation. He was requested to state this in writing that it might be presented at the Club Meeting of this date.

Regular Meeting, March 16, 1895.—Present: President George S. Webster, Vice-Presidents A Falkenau and John L. Gill, Jr., Directors Edward K. Landis, Charles L. Prince, Edgar Marburg, Henry Leffmann, W. C. Furber, the Secretary and the Treasurer.

The Treasurer's report showed:

Balance from January	$912 22	
Amount received during February	637 20	
		$1,549 42
Amount expended during February		509 62
Balance February 28, 1895		$1 039 80

The Treasurer reported that his bond for $2,000 had been drawn up by the American Surety Company, and sent for signature and witness, to be afterward returned for counter signature and entry. Upon motion, the Secretary was ordered to keep the bond in his personal custody upon its receipt in completed form.

The Secretary reported that he had succeeded in arranging with Mr. Annear to furnish the Club with 600 copies of the List of Members, containing also the Constitution and By-Laws, without any extra charge.

A communication was presented from the Chairman of the Committee on Gauges of the American Society of Mechanical Engineers, accompanying a report of the Committee, recommending the adoption of thousandths of an inch for gauges for measuring thickness and diameters of sheet metal and wire. The matter was discussed in favor of the recommendation, and ordered to be presented to the Club at its meeting on this date.

The Finance Committee reported that they had approved bills for payment to the amount of $124.

The Publication Committee reported that they had obtained an estimate from the Avil Printing Co. for publishing the Club's Proceedings, but as it was only slightly lower than that of the present publishers, it was thought advisable not to make any change.

The Committee also presented a proposal from Mr. John C. Baker, to solicit advertisements for the Proceedings. The proposal was referred back to the Committee with instructions to examine fully into the matter and make whatever arrangements seemed to be for the interest of the Club.

The House Committee reported that the building and its furnishings were in bad condition, especially the carpets, and that they would obtain and present estimates on the cost of desirable improvements at the next meeting.

The Committee's proposal to put the portraits of past Presidents in one or more large frames was approved.

Mr. Furber suggested that an engraved card of invitation to meetings be prepared, to be sent to those whom members desired to invite. Referred to the House Committee with power to act.

Mr. William J. Hoyt was duly nominated and elected to fill the vacancy in the Board, caused by the resignation of Professor Silas G. Comfort.

The Information Committee reported that Mr. F. H. Newell would read a paper before the Club on April 6th, and also that a stenographer had been engaged to take a shorthand record of papers and discussions at the Club Meetings.

Special Meeting, March 23, 1895.—Present: President George S. Webster, Vice-President John L. Gill, Jr., Directors Edgar Marburg, Henry Leffmann, Charles L. Prince, William J. Hoyt, W. C. Furber, and the Treasurer.

The meeting was called at the request of the Publication Committee, to consider the proposal of J. C. Baker, in reference to the soliciting of advertisements, as modified by this Committee. Professor Marburg submitted the credentials of Mr. Baker, and reported that the Publication Committee had held several meetings to consider this matter. A draft of the proposed articles of agreement between the Club and the advertising agent was submitted, also a proposed form of advertising contract. After considerable discussion, the proposed articles of agreement were approved, and it was resolved that further details be left to the Publication Committee with power.

CONTRIBUTIONS TO THE LIBRARY.

From December 15, 1894, to March 15, 1895.

From Professor H. T. Bovey.

Strength of Canadian Douglas Fir, Red Pine, White Pine, and Spruce.

From Bureau of Education, Washington, D.C.

History of Higher Education in Rhode Island.
History of Education in Maryland.

From Theodore Cooper.

New York and New Jersey Bridge Company—Hudson River Bridge—General Specifications for Its Construction.

From Cornell University.

Register, 1894–'95.

From E. L. Corthell.

Tehuantepec Isthmus Railway.

From A. C. Cunningham.

General Specifications for Structural Steel.

From Theodore N. Ely.

Catalogue of the Exhibit of the Pennsylvania Railroad Company at the World's Columbian Exposition, Chicago, 1893.

From Rudolph Hering.

Water Purification.

From C. G. Hildreth.

Holly Manufacturing Company's High Duty Pumping Engines.

From C. E. Howe Co.

Business Directory of Philadelphia, 1895.

From Howson & Howson.

Patent Centennial Celebration, 1891.

From Institution of Civil Engineers, London.

Abstracts of Papers in Foreign Transactions and Periodicals.
Deep Water Quays, Newcastle—Scott.
Friction in a Water Main—Friend.
Indian River Steamers—Callaway.
Prevention of Silting—Kennedy.
Rajkot Water Works, Bombay—Booth.
Windmills for Raising Water—Griffiths.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit is given the PROCEEDINGS.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XII.] JULY, 1895. [No. 2.

VI.

METHODS AND RESULTS OF STREAM MEASUREMENTS BY THE UNITED STATES GEOLOGICAL SURVEY.

By F. H. NEWELL, in Charge of the Division of Hydrography.

Read April 6, 1895.

ONE of the greatest of the resources of the United States, and one concerning which comparatively little has been said, lies in the running water. This resource, while by no means undeveloped, is still far from being thoroughly utilized, or even appreciated. From the permanence of its character, it deserves more consideration than has been assigned it in the past. The water resources include not only the employment for power—the item which occurs first to the eastern mind—but also for agricultural purposes and for community supply.

Water powers may be said to have reached their culminating importance several decades ago, and while few of note have been absolutely abandoned, there has been less relative growth in this line of development than in others. Among the chief of the disadvantages has been the immobile character of this power —the necessity of employing it where found. Water power, unlike coal, could not be moved for use near lines of transpor-

tation, nor brought to the centers of population. Within the past few years, however, there has arisen a new branch of engineering which has enabled, in effect, the water powers to be carried long distances and utilized at the very doors of great cities, or along the highways of communication. This—electrical engineering—has, with the vigor of youth, attacked the old problem of water power, and bids fair to solve the difficulties surrounding the employment of one of the greatest of Nature's forces. Thus it is, that the subject of water resources is not only of importance to one class of professional men—the hydraulic engineers—but also to a large number of the electricians.

The interest in our rivers is, however, not centered in the possible power available, but extends to wider circles. The possibility of developing agriculture to an extent unthought of in the past is now calling forth the efforts of engineers and political economists in all parts of the country. The United States includes within its boundaries vast areas of land suitable for the sustenance of a large agricultural population in every respect save one, and that one is the lack of rain at the proper times and seasons. The soil of these arid wastes is usually of extraordinary fertility, and when watered, produces crops of astonishing quality and magnitude. The National Government still owns one-third of the whole area of our country, exclusive of Alaska, and Uncle Sam is still rich enough to give each of us a farm, and a farm of most excellent soil, if we want it without water. Here the problem of water assumes the dignity of a national question.

The rapid development of urban life, resulting from the increase of wealth, the enlarged opportunities for enjoyment of social intercourse, so attractive to all peoples, has necessitated the most earnest consideration as to possible sources of water supply for the multitudes gathered in our cities and large towns. How to provide an abundance of pure, health-giving water, is the perplexing question confronting the city engineers of every State. In a few rare instances there are available certain unquestionable methods, but for the great majority of cities, water must be obtained from streams draining catchment areas upon which settlement has already progressed. For the inauguration of new systems, or the enlargement of old, it is essential that a thorough

knowledge be obtained of the character of this catchment basin, the amount of water available day by day and year by year, and all of the other factors dependent upon topographic and cultural conditions. In order to preserve for municipal supply the catchment basins, it is already necessary, and will be more so in the future, that the cities seek the aid of the State, or of the National Government, in holding forever large tracts of land, most of which are by nature unfitted for agriculture, as woodlands or great parks, and from which unpolluted waters may be obtained.

An investigation of water resources is thus a preliminary to considerations of the development of power, of agriculture, and of municipal supply. It is one in which not only the engineer is concerned, but the citizen as well, as upon full and correct information must depend the operations leading to the best development of the country. The United States Geological Survey, in its field operations, has been brought constantly in contact with all of these questions, since its surveying parties in the construction of the preliminary topographic maps, and in the study of rocks and soils, the mineral resources and their development, have penetrated nearly every nook and corner of this great country.

As might be expected, the first interest in the water supply of the country has come to the Geological Survey through its work in the public land area. It was first authorized to investigate the arid lands, but with the growing interest shown in the results of this work and of the comparisons with eastern streams, a steady demand has arisen that the Geological Survey collect facts relative to other undeveloped portions of the country, especially concerning the rivers rising in the wilderness of the great Appalachian area. Thus it is that the progress of field work in hydrography has been from the arid mountains of the West to the forest-clad slopes of the East. The opportunities and the wants of the West are by no means satisfied; but inasmuch as the survey is national, there is a feeling prevalent that its work must not be confined to any one section.

It should be clearly stated that the work of the Geological Survey is in no sense one of development, but rather is preliminary toward development. Its business is to explore, and from

its explorations, careful measurements and examinations, obtain information of such character that projects of various kinds can be intelligently discussed in their broader relations. It has sometimes been assumed that, because the Geological Survey has published information concerning the possibilities of development in one line or another, that therefore the National Government would take the matter in hand; but I think nothing can be further from the objects of the Survey, or more destructive to such objects, than the being involved in the execution of any plan to a greater extent than furnishing an impartial statement of the resources upon which such plan is based.

Problem of Public Lands.

As before stated, Congress has control of one-third of the area of the United States, the greater part of this land being open to entry and settlement under the provisions of the Homestead and similar acts. Probably a small fraction of 1 per cent. of this vast area is suitable for agriculture by what is known as "dry farming"; that is, agriculture without irrigation. As to how much can be ultimately reclaimed by means of irrigation, there is still room for doubt, as a full knowledge has not yet been obtained concerning the total available water supply and the quantity of water absolutely necessary for the cultivation of any given tract; but it may be safely assumed that not more than 5 per cent. of the land area will ever be thus utilized, even with the utmost economy of water and extraordinary development of systems of irrigation. The greater part of the public land, two-thirds at least, must always be held for grazing, and one of the most important considerations, after that of water for agriculture, is the obtaining of stock water, and even more than this, the protection of the native and introduced forage plants on these millions of acres of grazing lands. Pasturing of stock upon public lands is absolutely free. Any person can put upon it any number of cattle, or horses, or sheep, or goats; and, as a result, accessible ranges have long since been overstocked, and the cattlemen, and especially the sheepmen, have penetrated the wildest portions of the country, their herds and flocks keeping down, and even absolutely destroying, the best grasses and young shrubs, and in

many places the young trees. There is no incentive, as in the case of private property, to preserve the forage plants; for if one stockman should desire to guard and keep the public range from destruction, he has no legal guarantee that some other man may not come in with his herds or flocks. Thus it is that there appears to be a race, as in the case of the extermination of the buffalo and the rapid destruction of the seal herds, to see who can do the most damage in the least time. It is not the purpose of this paper, however, to describe the ways of the cattlemen in his efforts, often illegal, to preserve ranges, or of the constant triangular warfare between the cattlemen, the sheepmen and the settlers. The point to be emphasized is this: That the protection of the grazing industry must be accompanied by a thorough knowledge of the possible water supply and the best methods of its employment, either for drinking or for encouraging the growth of forage plants.

A relatively small proportion, say about 10 per cent. of the public lands, is actually desert and of no use except for saline minerals accumulated in the depressions, and of the balance of the public lands, about 15 per cent. of the whole may be considered as forests or woodlands, valuable not only for lumber, mining timber, fence posts and firewood, but also to a certain extent as conservators of water supply. The subject of the forests and of their relation to the development of the country is, however, one which at this time must be slighted because of its magnitude.

The value of the public lands and the legislation concerning them is thus seen to rest directly upon our knowledge of the water resources, more even than upon the mineral wealth which is now fairly exploited. The Division of Hydrography of the United States Geological Survey is systematically working to obtain the broadest possible knowledge of this subject consistent with limited appropriation, and is doing work in each of the several States and territories containing public land, and besides this is carrying on measurements in important localities in other portions of the country. The whole scope of the work of the survey has already been described by the Director (The United States Geological Survey and its Methods of Work, Charles D.

Walcott, PROCEEDINGS OF THE ENGINEERS' CLUB OF PHILADELPHIA, January, 1895), but reference should be made here to a few of the details which bear to a greater or less extent upon the hydrographic investigations.

The preparation of the topographic map of the country is fundamental to nearly all of the investigations of the survey, since the representation of results can only be correctly done upon a base map which shows elevations of the surface as well as cultural conditions. The completed map shows not only the position of the streams and their minor tributaries, but also the slopes of the country and the total catchment area above any given point. The facilities for field work offered by topographic parties and the data collected by them has greatly aided in the proper establishment of river stations, and as far as possible the hydrographic work follows the mapping, although as a matter of course it cannot be held back to await the survey of all parts of the country.

The investigation of water supply touches also upon the geologic work, as well as the topographic, in that many of the phenomena of springs and of the occurrence and disappearance of water at various places can only be explained by the structure and physical features of the rocks. The run-off from any given catchment area, as is well known, is largely dependent upon the character of the geologic formations, and comparisons of different drainage areas can only be made with confidence when all of these facts have been ascertained. Thus it is that the Hydrographic Division stands in close relation with the greater features of the Geological Survey, and while making use of the results of the work of the topographer, the geologist and the chemist, obtains a new class of facts and groups these in their new relations. Going outside of the data collected by the Survey, this Division utilizes the information obtained by the Weather Bureau relating to precipitation and its fluctuation and distribution over the country. One fact to be pointed out, however, is that this investigation of water supply is essentially a survey, its fundamental facts being obtained through instrumental work in the field, and is not, as is the case of most bureaus of the government, an office organization tied to one spot.

Location of River Stations.

The selection of points at which observations of river discharge are to be made is governed by the character of the data which should be acquired, and the probable value of the results, not only from their furnishing details concerning the particular stream, but also from their utility in supplying facts which can be applied in a general way to other streams of the region. It is of course impracticable to measure all; but if one or more important rivers in each State can be measured, the results can possibly be applied to other streams coming from catchment basins of similar altitude and under like climatic conditions. It is possible, however, to make a wide selection of points at which measurements should be made, as the subject is one as yet hardly touched upon, and there is demand for information concerning nearly every stream. Thus the matter of cost and convenience becomes the decisive factor, since the amount of money available is relatively exceedingly small.

In each of the larger drainage basins, especially of the West, points have been selected at which, with due regard to results, the work could be carried on with the least delay and expense for transportation. These points are usually near railroads, and, wherever practicable, river gages have been attached to railroad bridges, record of height of water being kept by employés of the company. Besides the river stations of the Geological Survey, records of heights of various streams are being kept by the Weather Bureau, by the Corps of Engineers, U. S. Army, and by the Mississippi and Missouri river commissions. The Weather Bureau stations are for the purpose of predicting floods, and are grouped in such positions as to report to central offices at points down stream from the place of observation. The other river records are kept partly as guides to inland navigation, and partly for the purpose of obtaining information necessary for permanent river improvement. Little attempt has been made to connect these records of the Weather Bureau with quantities of water discharged, as this is an engineering operation which requires field parties and field equipment.

Instruments and Methods.

In order to make a complete study of a stream, it is necessary to have an estimate of quantity of water flowing day by day throughout the year. It is, however, impracticable to make direct measurements each day in the majority of cases, and therefore less direct methods are resorted to. These consist of keeping record of the height of water, and by simple computations interpreting this height in terms of quantity. For this there are required two classes of field assistants; the one to keep regular readings of the height of water at short intervals throughout the year; the other to make measurements of quantity, such that the relation of height of water to discharge may be known. For the purpose of keeping record of height of water many automatic instruments have been devised, some of these of great ingenuity; but for the work of the Geological Survey it has been found, after many trials, that better results can be obtained by the simple method of having a man residing near the spot note down, once, twice, or three times a day, the height of water upon a suitable device, or as measured directly. The recording nilometers, or tide gages, give excellent results when carefully installed, and when they can be watched by skilled men; but almost without exception these fail when placed in charge of the ordinary unskilled man, such as can be obtained where the river stations are located. It is evident, however, that, if several hundred dollars could be spent in a thorough equipment and in such protection that an instrument could be left safe from meddling, it might be possible to obtain very accurate continuous records; but under present conditions economy forbids such expenditures.

The river gages consist usually of vertical rods, firmly fastened, and marked to feet and tenths of foot. Occasionally, inclined rods, following the slope of the bank, are used, these being marked to equivalent vertical feet and tenths. In a few cases the height of water is ascertained by a weight lowered by wire cord from a bridge. The records are kept in small note-books, and copies are mailed to the local state office once a week, and, after compilation, are forwarded to the office at Washington for preservation.

Quantities of water are usually measured by means of various

forms of current meter. Floats are occasionally used, but for convenience and economy of time the meters are preferred. It is of course impracticable to construct weirs on streams of considerable size, but in a few instances river discharges are estimated by using dams already constructed as weirs.

For the use of this survey a considerable number of meters have been tried and various improvements suggested in the lines of lightness and strength. The river stations being at considerable distances apart, and often at points difficult of access, it is necessary to have instruments which can be readily transported. There is, however, no one meter which has been found applicable

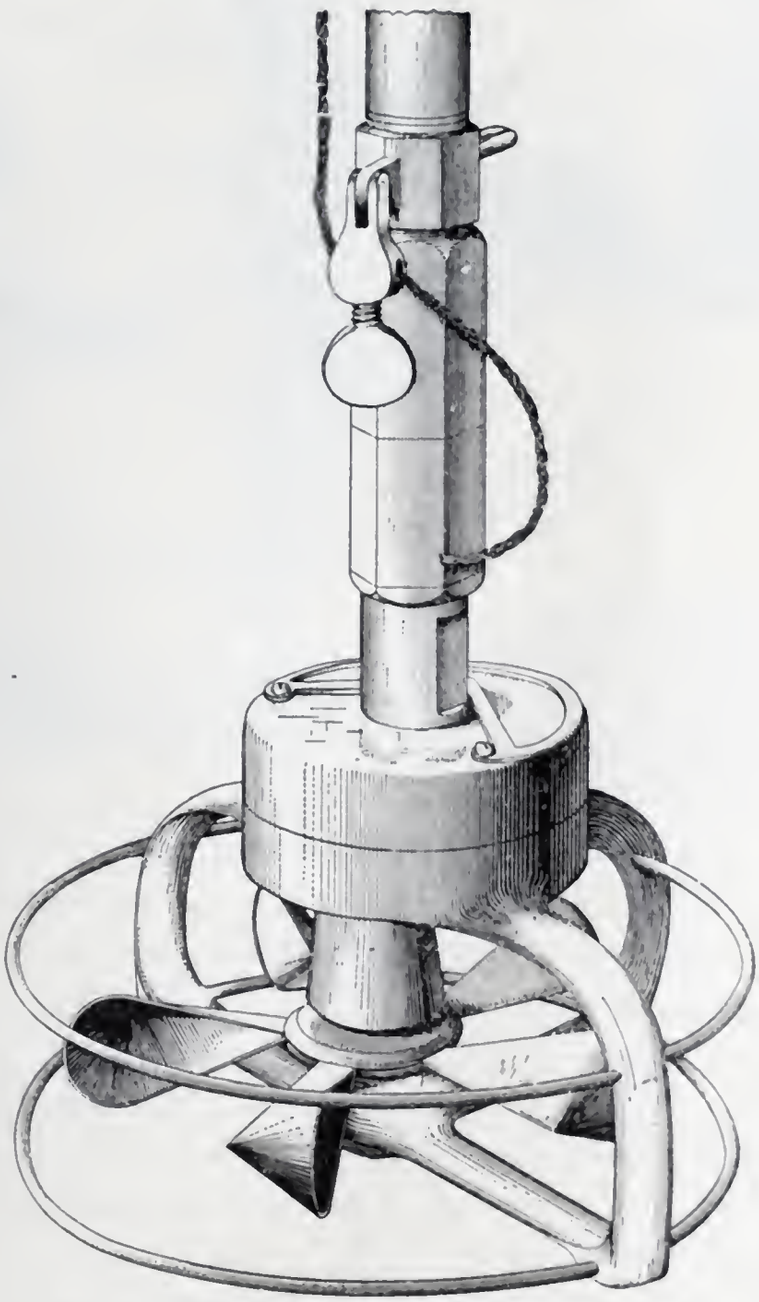


Fig. 1.—The Colorado Current Meter.

to all conditions, and the hydrographers of the Survey each have individual preferences as to kind of instrument. A considerable number of the direct recording cup-shaped meters (Figs. 1 and 2)

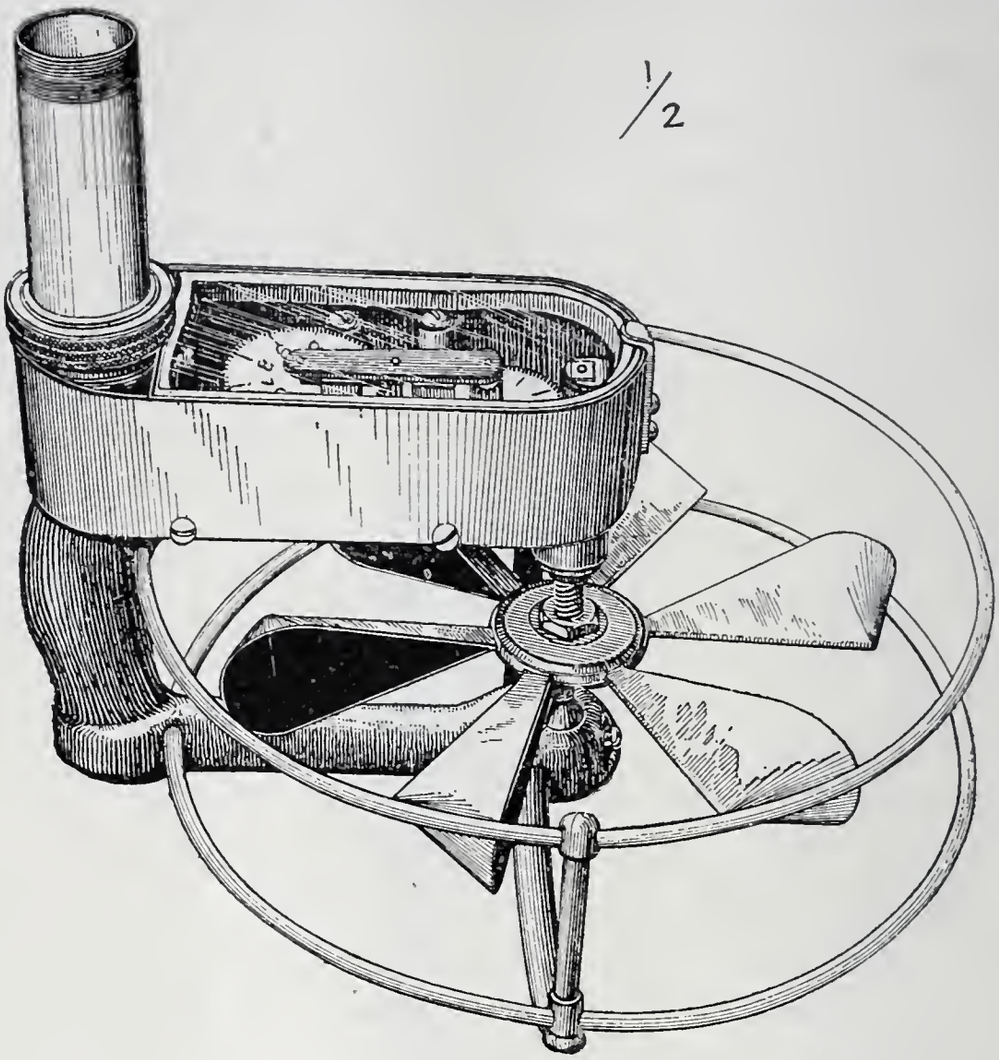


Fig. 2.—The Improved Colorado or Lallie Meter.

have been used, and these are preferred for shallow streams, and especially for canals and ditches. The cup-shaped wheel has, however, the disadvantage of indicating a velocity too great, if the wheel is not held very nearly horizontal. A form of meter greatly liked by the men who have worked on torrential streams, is the small Haskell meter (Fig. 4), made with only two flukes on the revolving wheel. This meter can be used either on a rod or suspended by cord from a bridge or other support, or can be swung over a stream and lowered to any desired point by means of suitable light cables and trolleys. This meter records electrically, and like all electrical devices, has the disadvantage of getting out of order, when in the field, in the most aggravating manner. For recording the revolution of various types of meters a

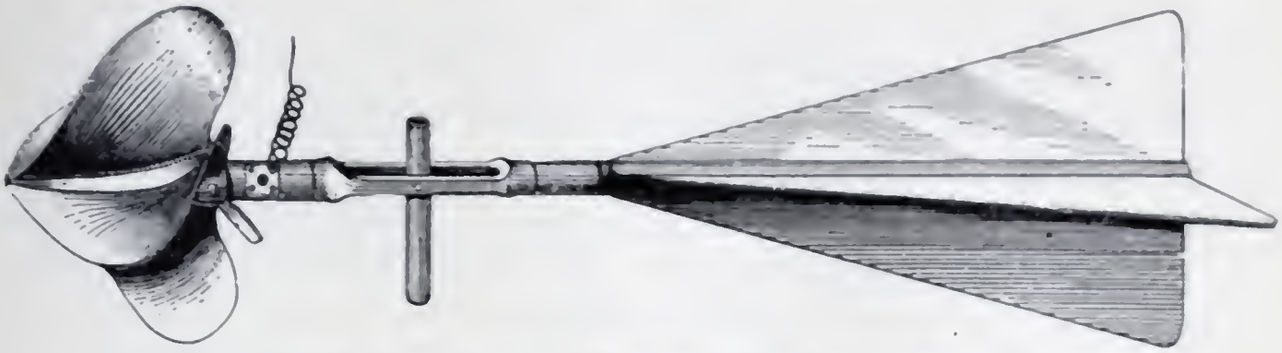


FIG. 3.—THE LARGE HASKELL CURRENT METER.

variety of registers has been used, and found to be fairly good under moderate velocities and with careful handling; but for all-around work, the simple telegraphic sounder, whose beats are counted, is preferred by the experienced hydrographer.

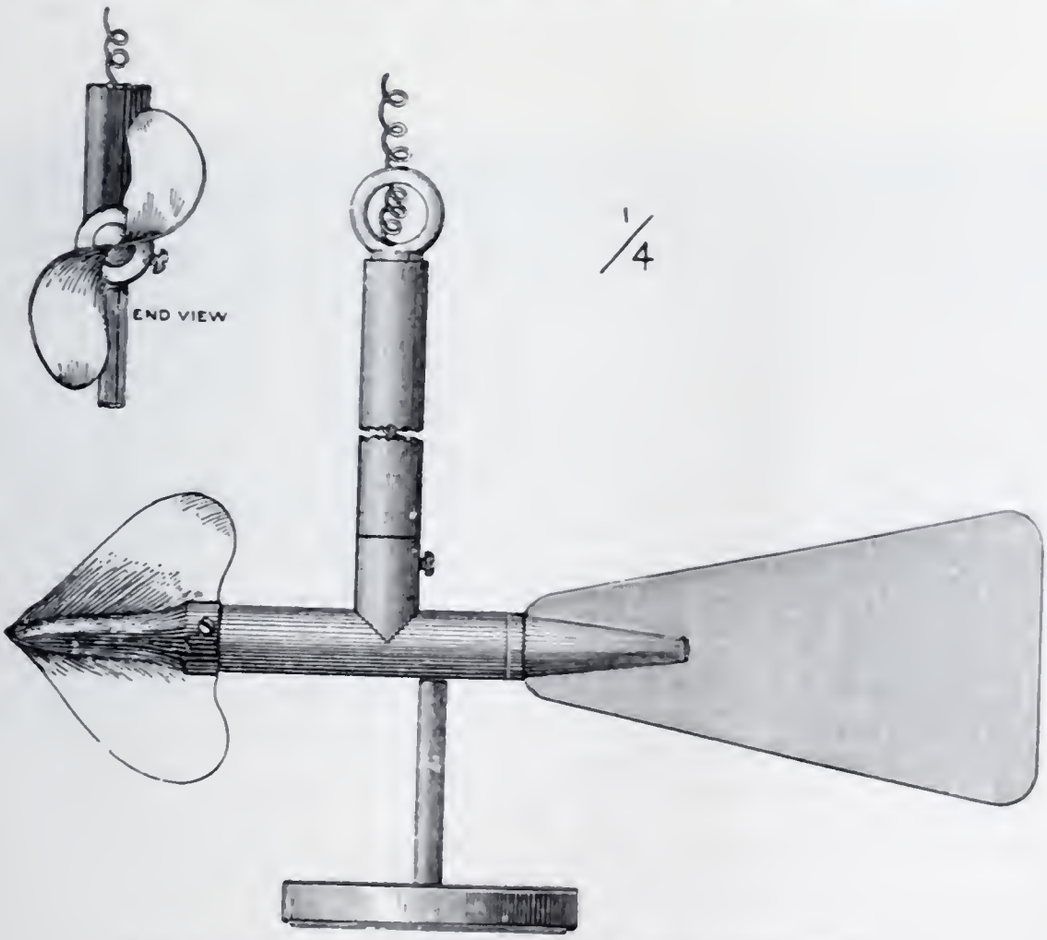


FIG. 4.—THE SMALL HASKELL TWO-FLUKED METER.

Long search has been made for some form of electric battery, convenient for field work, which should be light, portable, strong and reliable. Nearly every kind of dry battery has been tried, and has been given up in favor of the more cumbersome wet cell, which, though bulky and constantly liable to breakage,

can be depended upon. The latest experiment, and one which promises to be successful, is the employment of very small so-called bisulphate of mercury (mercuric sulphate) batteries, less than two inches in height and a little more than an inch in thickness, made for medical purposes. These, if cleaned and recharged at short intervals, do away with one of the difficulties incident to the use of an electric meter.

The meters are handled usually from a boat, a bridge, or a suspended car. Wherever a bridge is convenient, and its piers do not obstruct the current, measurements can be made with comfort by the hydrographer. At most important points, however, bridges are not available, and if the stream is not too wide, a wire cable is stretched across, and a boat attached to the cable by a traveling pulley. The meter is then used from the projecting bow of the boat, generally from a rod allowing it to be placed at

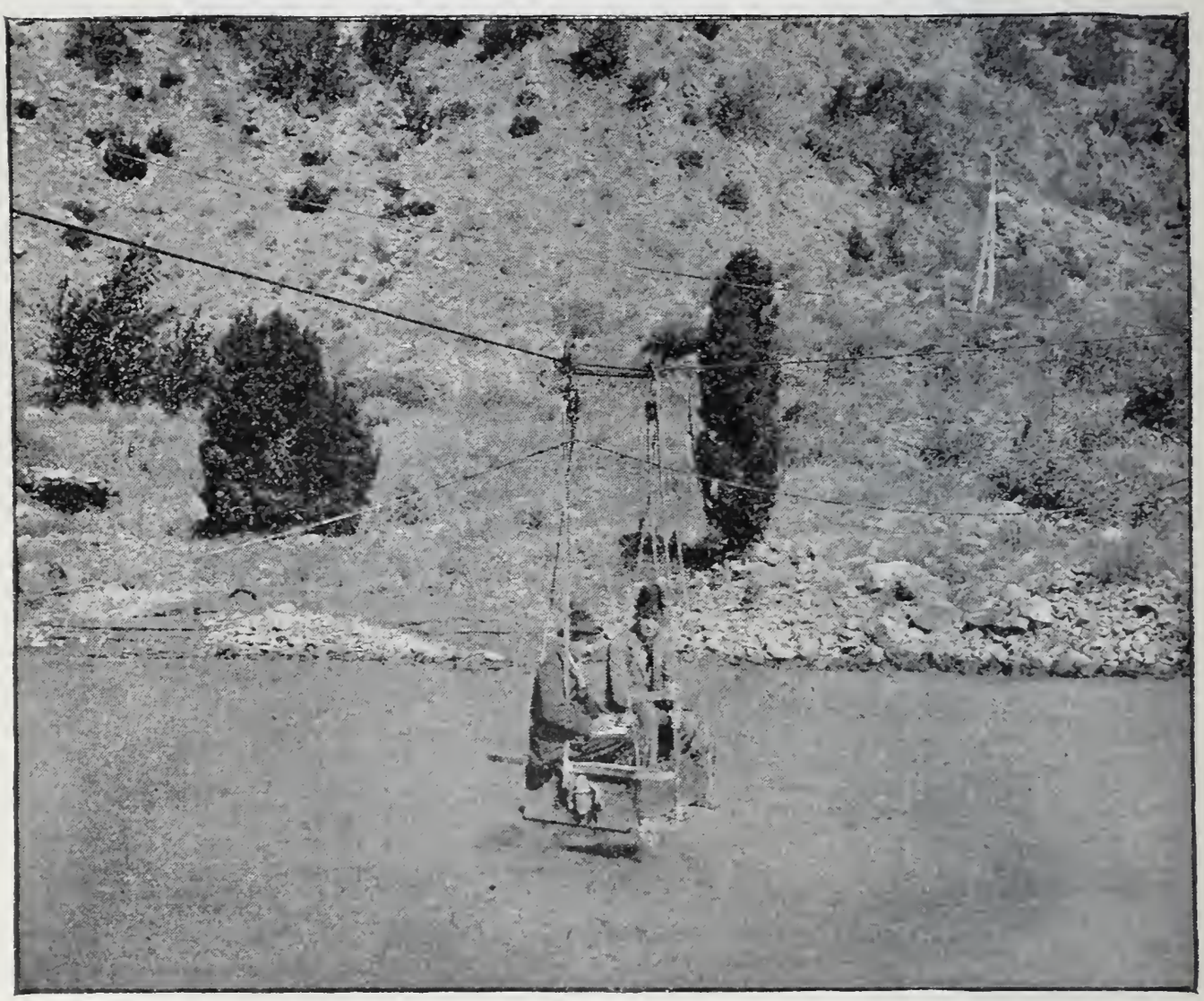


Fig. 5.—Method of Using the Current Meter from Suspended Car.

various depths. In a few instances, where the current is such that a boat cannot well be used, a small box or car, as shown in Fig. 5, has been suspended from pulleys running on the cable, and the hydrographer, and sometimes his assistant, work from the car. If, however, the span of the river is so great that a stout cable cannot be placed across it, lighter wire cables have been used, and the meter, as above stated, run out on these and lowered by halyards.

By the methods above mentioned the current meters can be placed successively in various parts of the stream and the velocity of the water ascertained at all places, both vertically and horizontally, in the cross-section, the relation of the revolutions of the meter to the speed of the water having been previously obtained by running the instrument at various speeds through still water. From the area of cross-section, and the average velocity with which the water moves, the quantity is computed for the particular height at which the water is then standing. By visiting the stream at various stages, the hydrographer is able to obtain the discharge corresponding to various heights of water, at low, medium and flood stages.

Rating Table.

The results of measurements of discharge for various heights of water are plotted upon cross-section paper, as shown in Fig. 6, in which the distance above the base corresponds to the height of water, and the distance from left to right, to the volume of the stream. The points thus located, in general fall in a slightly curved path or line, variations on one side or another being due to differences of conditions at the time the measurements are made, or to inaccuracies resulting from fluctuations of river height. The hydrographer, having in mind the relative degree of accuracy of the various measurements, sketches through these points a smooth line which represents the probable relation of discharge to height of water, independent of minor considerations. From the curve thus obtained, values are taken for each tenth of height of gage-reading, constituting a table from which the discharge corresponding to any given height can be had.

It has been long since pointed out that in large streams, at

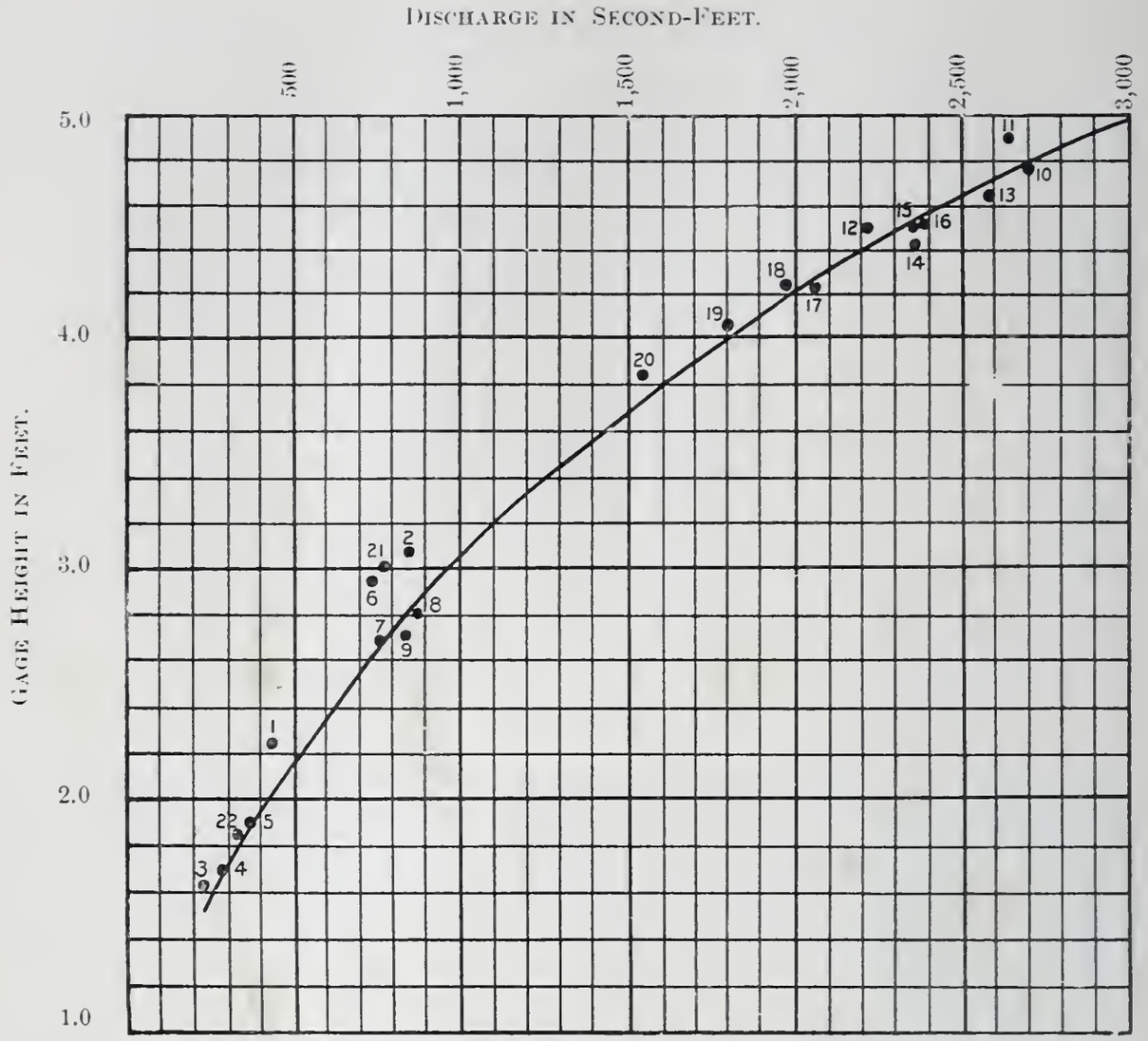


Fig. 6.—Rating Curve for Station on Arkansas River, at Canyon, Col.

least, the relation of gage-height to discharge is not fixed, but varies according as the river is rising, falling, or stationary, and is modified by the direction and velocity of the wind. In the case of the smaller non-navigable streams and mountain torrents, where it is desirable to obtain with fair degree of approximation the average daily and monthly discharges, errors arising from this source must be neglected, as it is usually impracticable to make a sufficient number of discharge measurements to cover all of the conditions of fluctuating streams and wind. The rating table, therefore, is constructed under the assumption that it will give the average discharge, and that while for any one day it may not be as exact as direct measurement, yet, taking a series of days, the average will be fairly reliable.

It has been a matter of great interest to compare a rating table made as above described with the results of later measurements.

The river channel at most localities is constantly changing, and in sandy streams the area of cross-section is liable to be increased by scouring, or diminished by filling, following the changing river height. Experience extending through a number of years has shown a somewhat remarkable persistency in the tendency of any one station to return to what might be called average conditions, so that the rating table based on a well-distributed series of gagings is often applicable for two or three years or more. Some of the rating tables are progressively changing in one direction or the other, but at well-selected localities the series of observations show little variation.

River Stations.

In this paper it is impracticable to enter upon a detailed description of the localities at which river measurements have been made by the United States Geological Survey, and reference therefore will be made to those in a general way, the complete data being found in official publications of results. (See papers relating to hydrography, in the Eleventh, Twelfth, Thirteenth and Fourteenth Annual Reports of the United States Geological Survey.) The principal series of measurements have been upon the following streams:

On the Gallatin, Madison, and Jefferson, headwaters of the Missouri; on the Missouri River itself near Townsend, Montana; on the Yellowstone River where it leaves the National Park; on the South Platte and various tributaries; on the North Platte and Laramie Rivers, and at the junction of the North Platte and South Platte; also on the Loup and Frenchman in Nebraska; on the Arkansas at a number of points from the headwaters down; on the Rio Grande in Colorado, New Mexico, and Texas; on the Grand, Green, Gunnison, and Gila Rivers, tributaries of the Great Colorado; and on the Colorado itself at Yuma; on the Bear River in Idaho and in Utah; on the Ogden, Weber, Provo, and other rivers of the Salt Lake area; on the Humboldt River in Nevada; on the Carson and Truckee in Nevada and California; on the headwaters of Snake River in Idaho, and on some of its tributaries in Oregon; on the Yakima River in Washington; and later on the Sacramento, Mokelumne, Tuolumne, Kings and

San Joaquin, and a few of the streams of southern California. Besides these western rivers, work has been begun on the Potomac, and details of flow studied concerning the Connecticut, Savannah, and other rivers of the east coast.

The results of the measurements and computations of daily discharge have been given, not only in numerical form, but plotted graphically, in order to show at a glance the behavior of the various streams, the time of the fluctuations, and to enable ready comparisons to be drawn. In the following figures, 7, 8, 9 and 10, diagrams of flow of representative streams have been

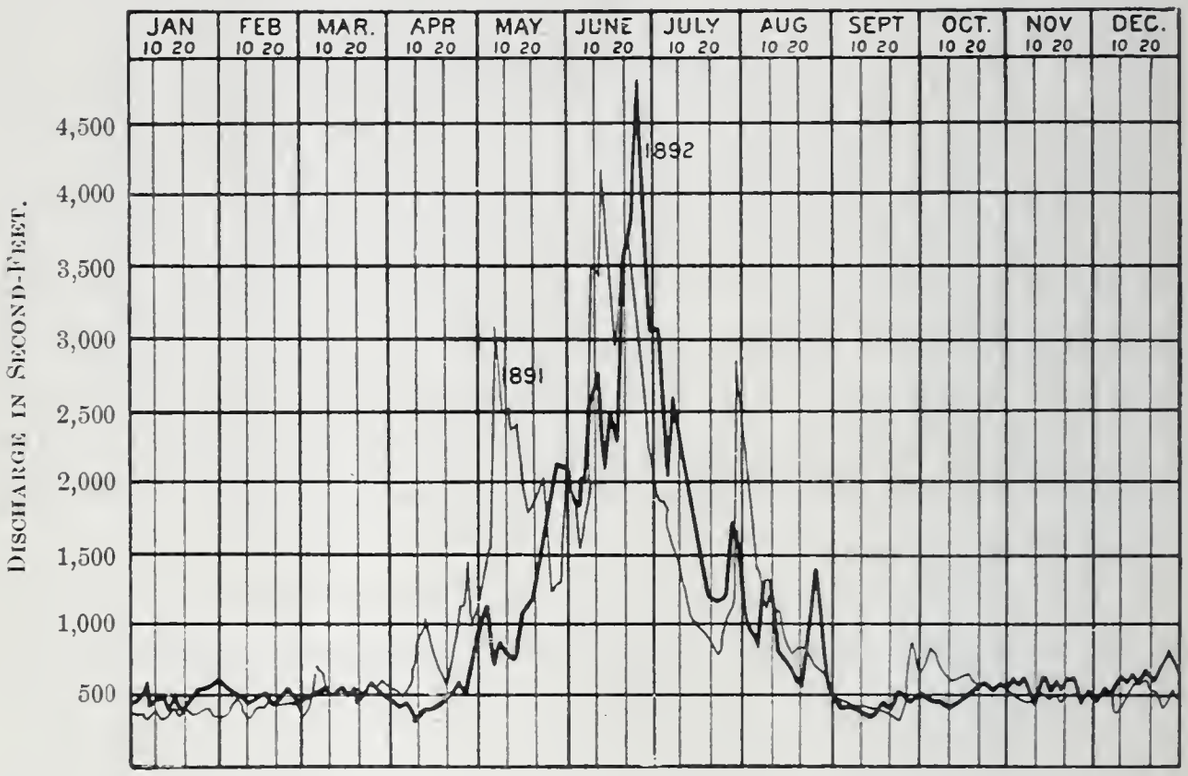


Fig. 7.—Daily Discharge of Arkansas River at Canyon, Colorado, for 1891 and 1892.

selected in order to illustrate these facts. In Fig. 7 is given the daily discharge of Arkansas River at the point below the Grand Canyon of the Arkansas, and above the city of Canyon, Col. Below this point a number of ditches and canals begin to divert the water, and further down upon the Great Plains large canals take, during the summer season at least, all of the water in the stream. Measurements have been made by the State Engineer of Colorado, and later by the United States Geological Survey, extending over a series of seven years, observations having been

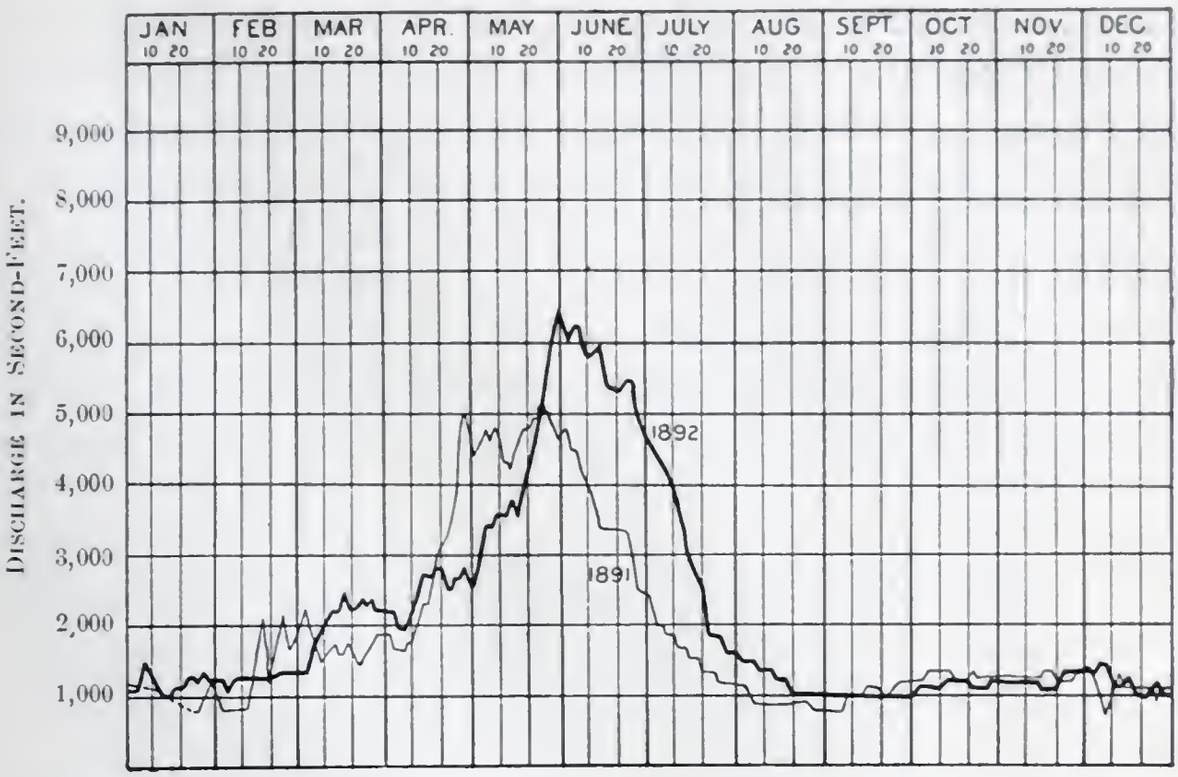


FIG. 8.—DAILY DISCHARGE OF BEAR RIVER AT COLLINSTON, UTAH, FOR 1891 AND 1892.

begun in 1888. This is one of the longest series of river measurements made in the West, and a comparison illustrates the great fluctuations which take place in the mean, monthly, and

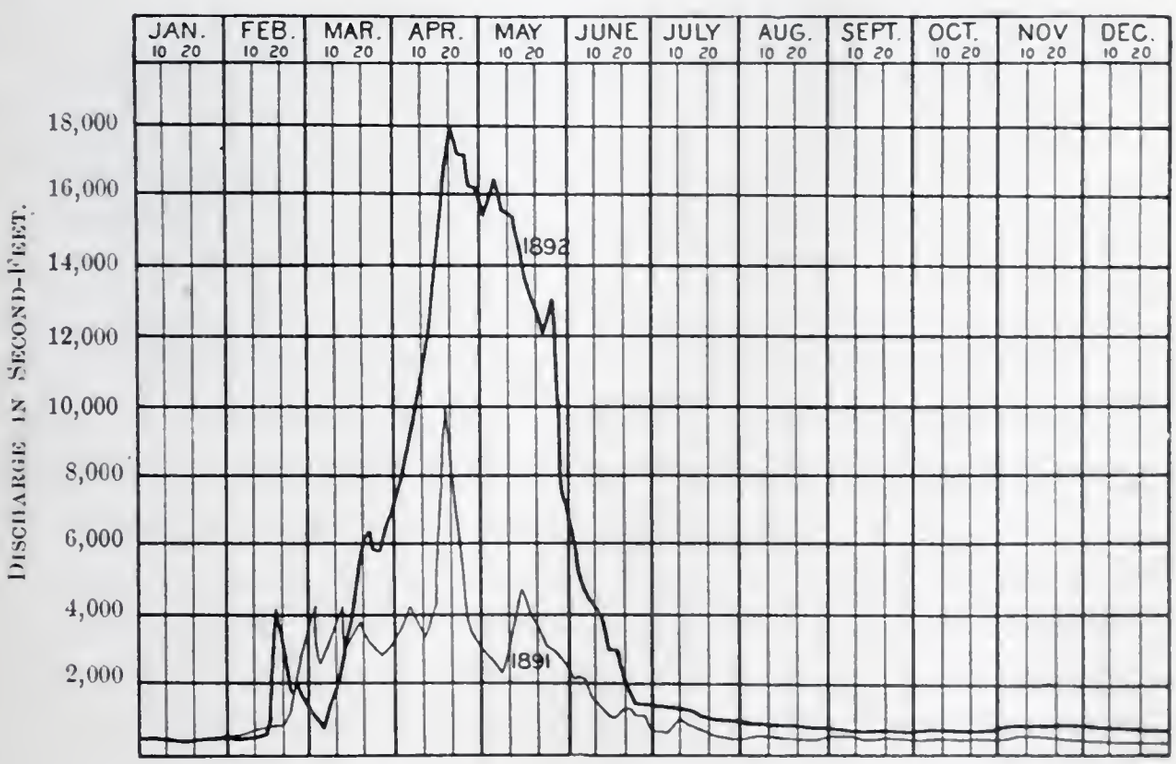


FIG. 9.—DAILY DISCHARGE OF OWYHEE RIVER AT RIGSBY, OREGON, FOR 1891 AND 1892

annual discharge. The diagram shows two years, 1891 and 1892, which, however, do not differ from each other by a very considerable amount. In 1891, as shown by the thin line, the first flood came in the early part of May, succeeded by diminished flow, owing probably to cold weather, and the second flood in the latter part of June, this falling off rapidly during July. In 1892 the spring floods were somewhat later, and the maximum, 4,750 second-feet, occurred about June 25th, followed by a nearly continuous decline similar to that of the preceding year, but a week or ten days later.

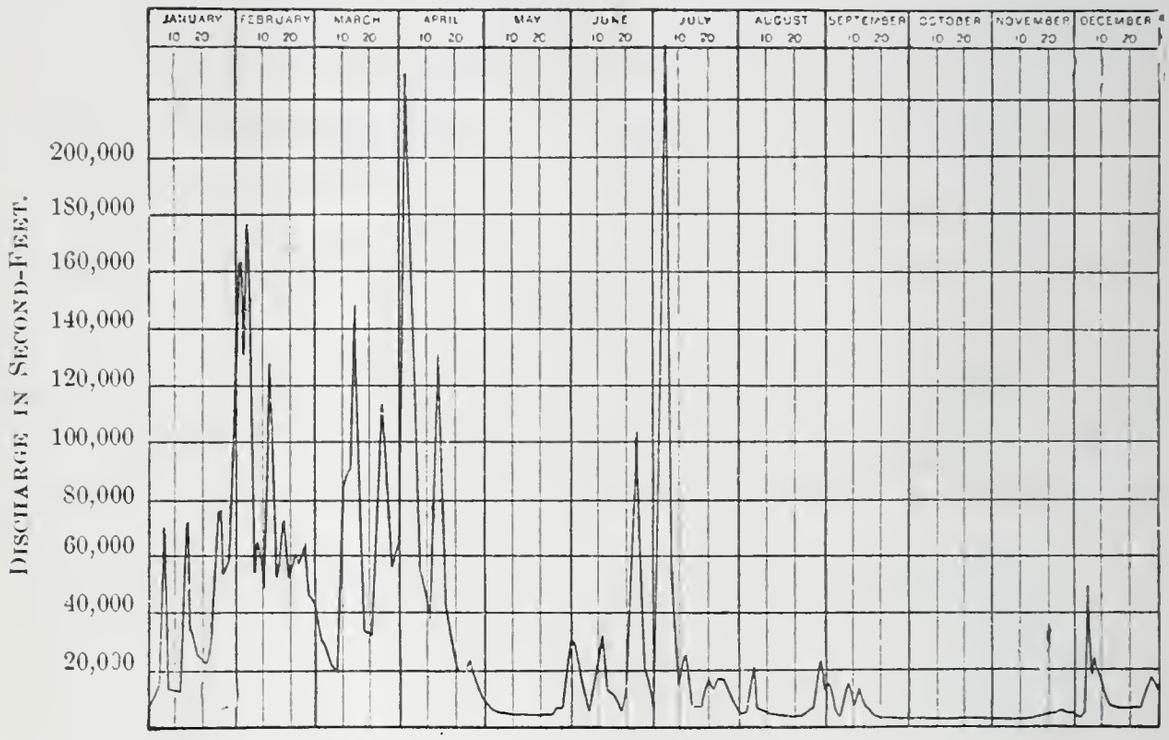


FIG. 10.—DAILY DISCHARGE OF POTOMAC RIVER AT GREAT FALLS, MD., 1891.

The next diagram, Fig. 8, shows the daily discharge of Bear River at Collinston, Utah, for 1891 and 1892. This is in marked contrast to the preceding in the smoothness of the figure, indicating a regularity of flood. In 1891 this was earlier and smaller than in 1892, but in general the behavior was the same. The notable regularity of rise and fall at once attracts attention, as being probably due to ponding of the water. This is the fact, the river being divided into two portions by the great marsh and overflow lake on the borders between Utah and Idaho. The floods from the upper river, due to melting snow, pass into the marsh, and by numerous channels find their way into the lake,

to be discharged later. One of the most important projects yet to be developed is the more complete utilization of this and similar opportunities for reservoiring flood waters.

Fig. 9 gives the discharge of Owyhee River, Oregon, a tributary of Snake River, which in turn discharges into the Columbia. This diagram well illustrates the difference which may be expected in the behavior of a stream, especially in the arid regions, on any two consecutive years. In 1891 the floods were low and somewhat irregular, but in 1892 they were strong and persistent, extending through May, but finally dropping to a summer and fall discharge not greatly exceeding that of previous years.

The diagram of discharge (Fig. 10) of Potomac River (The Hydrography of the Potomac Basin, by Cyrus C. Babb, *Transactions American Society of Civil Engineers*, Vol. XXVII, pp. 21-38, July, 1892), above the city of Washington is of interest for comparison with the figures just given, as being typical of most of our large rivers which do not depend upon the snows melting upon the high mountains. As will be seen at a glance, the floods are exceedingly irregular, occurring at almost any time of the year, swelling to a great volume, and returning with almost as great rapidity to low-water conditions.

For many of the rivers on which long series of measurements have been made there are recognizable certain characteristics of flood and low-water traceable to the topographic and resulting climatic conditions prevailing in the drainage basins. The streams which rise in the high, snow-capped peaks of the Rocky and Sierra Nevada Mountains have persistent, regularly recurring spring floods, which can be depended upon to bring wealth to the famished plains below. In sharp contrast to these are the rain-fed streams coming from areas of less elevation and more gentle slope. Many of these, especially in the West, are almost, if not quite, dry, for months or years at a time, and their broad sandy channels are the only evidences that at irregular intervals violent floods are liable to occur. Between these two extremes are to be found every variation, but in spite of the apparent irregularity it is possible to ascertain in a broad way the regimen of each class of streams, and knowing this, to adapt works of improvement to meet these prevailing conditions. These dia-

grams, therefore, serve as a suggestion of what may be done toward obtaining a knowledge such as to render possible the best employment of each source of water supply or of water-power.

Run-off.

The measurements of volume of streams in various parts of the country afford means of comparison of the volumes of delivery which, as is well known, are not proportional to the area drained, but to climatic and topographic conditions. For example, it might be pointed out that, taking the Ohio, the upper Mississippi, and the Missouri, the former, with the smallest drainage basin, has the greatest discharge, while the latter, though of great length and importance, is relatively insignificant. These comparisons might be extended, but the broadest conception of the subject can probably be obtained through a study, not of actual volumes, but of the average quantity of water drained from each unit of surface of the whole country. For convenience of such comparison the discharges of the streams or "*run-off*" have been computed in terms of depth of water drained from the surface, this being stated in inches, as is customary in the case of rainfall. Knowing the average precipitation and the average run-off, the relation between these can be ascertained under various conditions. The accompanying diagram, Fig. 11,

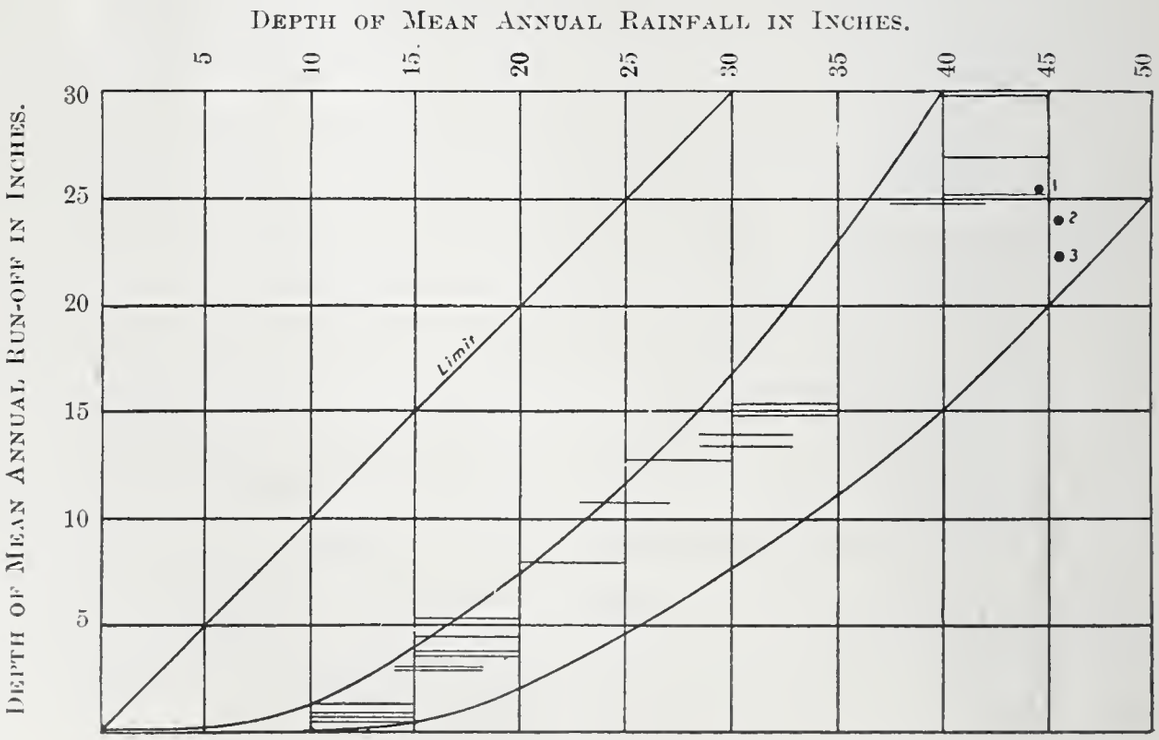


Fig. 11.—Relation of Run-off to Rainfall.

shows in a broad way this relation as dependent upon the topographic conditions, it being assumed that the climatic factors are governed largely by the elements of altitude and slope.

On this diagram, Fig. 11, the height above the base represents the depth in inches of the mean annual run-off, or the amount draining from the surface, and the distance from left to right, the depth of rainfall upon the surface of the drainage basin. The diagonal line represents the limit or the condition when all of the rain falling upon the surface, as upon a steep roof, runs off; the horizontal base, the conditions when none of the water flows away. Between these are the two curved lines, the lower representing the assumed condition prevailing in a cachment basin of broad valleys and gentle slopes, from which as a consequence there is relatively little flow, and the upper curve, an average condition of mountain topography, from which large quantities of water are discharged. For example, with a rainfall of 40 inches on an undulating catchment basin, about 15 inches is discharged by the stream, while from steep slopes 30 inches runs off. With less mean annual rainfall the relative run-off is far less, as for example, with 20 inches, about 7 inches of run-off is found in steep cachment basins, and about 3 inches on the rolling plains and broad valleys of less rugged topography. Following these curves down, it would appear that as the average yearly rainfall decreases the run-off diminishes rapidly, so that with from 10 to 15 inches no run-off may be expected on many areas, and from 2 to 4 inches from the mountains. There is an apparent exception to this, in that with very small annual rainfall the precipitation often occurs in what is known as cloudbursts, large quantities of water falling at a surprisingly great rate. Under these conditions the proportion of run-off to rainfall increases, as the water does not have time to saturate the ground.

These curves should not be regarded as exact expressions, but as indicating general relationships and as showing graphically deductions based upon long series of observations of quantities not determined with exactness. Computations of this relation made in various parts of the country have, when plotted graphically, fallen near or between these curves, according to the char-

acter of the country from which the water was discharged. On the figure are shown three average determinations, numbered 1, 2 and 3, representing respectively the relation of run-off to rainfall, for the Connecticut, Potomac and Savannah Rivers. The horizontal lines indicate determinations made for western streams coming from areas of small precipitation. The exact amount of rainfall is not known, as the observations are not representative of the conditions prevailing upon the mountains, and therefore the horizontal line has been used instead of a dot, as indicating the probable range of rainfall, as, for example, being from 10 to 15, or from 15 to 20 inches. The height of these short lines above the base indicates the average annual run-off of the basin, a quantity which has been determined with considerable accuracy according to the method just described.

The observations of depth of run-off, and computations made upon the assumptions contained in the foregoing pages, as shown graphically upon diagram 11, have been plotted upon a map of the United States, affording material for sketching a generalized map of the distribution of run-off. This, in general appearance, resembles the conventional map of mean annual rainfall, and can be compared with it. The data for such a map are by no means as complete or satisfactory as those for the rainfall map, but the resulting sketch has been deemed worthy of publication in preliminary form as one of the plates of a forthcoming volume of the United States Geological Survey (Fourteenth Annual Report—Part II, Plate V), to which reference should be made for more detailed statements of the general subject under discussion.

[During the reading of the above paper, Mr. Newell exhibited and referred to a large colored map showing the vacant public lands of the United States, and the areas reserved or disposed of by the National Government; also, diagrams illustrating the present area of the lands as classified according to its availability for settlement, these being original manuscripts from which illustrations are to be made for a paper accompanying the Sixteenth Annual Report of the Director of the United States Geological Survey. He also called attention to large maps showing the mean annual rainfall and mean annual run-off, these being

copies of illustrations prepared for the Fourteenth Annual Report of the Geological Survey, now in the hands of the printer. Later, by means of the lantern, pictures were exhibited bringing out more clearly many of the points briefly mentioned in the paper. Among these were photographs of characteristic scenes on the public lands of the United States, showing the vast extent of unoccupied arable prairie land, the cattle ranges, with cattle in the distance, flocks of sheep, and the grazing lands of the foothills. Next were given scenes in the high mountains, where, from the steep slopes, with cañons filled with perennial snows, come the streams furnishing waters to the fertile plains and broad valleys. Characteristic views of the lower channels of these streams, with sandy beds, dry for a great part of the year, were also exhibited, and the lava plains and desert areas, which form a notable percentage of the West, depicted. Pictures of notable artesian wells, of reservoir-sites, and of windmill machinery also brought more clearly to the audience a conception of the methods of utilizing the water supply according to its character. An exhibit of various forms of current-meter and recording devices closed the paper.]

DISCUSSION.

Mr. John E. Codman.—For the past eight years I have had charge of the collection of the data for the Bureau of Water in relation to the flow of the streams in Eastern Pennsylvania. The observations were started in 1883, when Col. Ludlow was Chief Engineer of the Water Bureau, and the object was the collection of data sufficient for the determination of the future water supply of the city. Mr. Hering was appointed engineer in charge of this work, and under his supervision accurate surveys of the eastern part of the State were made, covering part of the valley of the Schuylkill, of the Delaware as far as the Water Gap, of the Perkiomen, of the Tohickon, and the Neshaminy. Maps and diagrams were made showing accurately all the data of the surveys and measurements of the stream flow. The volume of water flowing in the streams was obtained in a manner very similar to that which we had given us this evening.

These observations, given on the chart before you, showing the yearly rainfall of 45 inches are a fair average of the amount of rain falling over the eastern portion of this State. This amount will in a cycle of years vary from as low as 32 inches to as high as 72 inches. The amount of rain flowing in the streams is very much the same as that shown to us. With 45 inches of yearly rainfall there are about 22 inches flowing in the streams of Eastern Pennsylvania. This quantity varies also, but not as much in proportion as the rainfall. In years when there is a heavy rainfall the proportion of water flowing in the streams is not as great as would be expected. During the year 1889 there was a remarkably heavy rainfall, but the quantity which flowed off in the streams did not increase in the same proportion; but in the following year, when there was a smaller amount of rainfall, the proportion flowing in the streams was greater, showing that the ground retains a storage capacity that must be distributed over a series of years. The months of May, June, July, August and September are the months of the greatest evaporation and the least stream flow. In 1889 we had the heaviest rainfall for these months on record, but the amount flowing off was not greatly in excess of that of other years. As before stated, a large proportion of this was held in storage and appeared during the following years. The flow of the streams also varies greatly from month to month. The flow of the streams in Eastern Pennsylvania, and in this climate, is almost directly opposite to that which was shown to us on these diagrams. You will notice that the stream-flow diagrams of the Colorado River show that the greatest volume of the stream-flow occurs during the months of May, June and July, whereas in the streams in this section of the country our greatest flow is during the months of February, March and April. This may be varied; take, for example, last year, we had a very heavy rainfall during the month of May; about one-half of the total flow of the Schuylkill for the year went over the dam between the 15th and the 30th. We may have during each month of the year the average amount of rainfall; but the amount flowing off in the streams will vary from the month of March, when we will have very nearly the total rainfall; to October, when perhaps there

will not be more than 2 per cent. The amount flowing off each month is not proportionate to the amount of rain falling, *i. e.*, we may have a very heavy rainfall, and the percentage of flow may not be a large one.

The method of measuring the stream-flow is similar to that shown by Prof. Newell. In all the observations that have been carried on for the past twelve years, it shows that, with 45 inches of rain falling on the surface we can count on nearly 22 inches of rainfall being found in the streams. The collection of data on rainfall and stream-flow to be of value must be extended over a series of years. Observations on the Schuylkill, Perkiomen, Neshaminy and Tohickon have been continued for twelve years.

Mr. John Birkinbine.—Mr. Newell's remarks, and his statements concerning what the United States Government is doing in reference to the gaging of streams, call forth the suggestion that the conditions influencing the value of water-powers in late years has materially changed. Each one here can recall some mill or industry now abandoned, which formerly was placed on the bank of a stream and was operated by water-power. These sites were not abandoned because the creek flowed elsewhere, although possibly the denudation of the forests on the drainage area made the flow less regular.

At the present an industry operated upon a small scale is handicapped in competition with others which are more pretentious, and it may not pay now to carry on milling or any other line of business at a rate which has for its only advantage a water-power, and to which the small amount of material must be conveyed to, or product carried from it by wagons. The application of electricity permits us to use the water-powers on the streams and convey the power by wire to considerable distances over difficult ground.

Mr. Newell emphasized the importance of re foresting our denuded areas. The United States Government is taking a hand in this work by creating reservations; New York has already established large state reservations, and Pennsylvania and other States may well follow this example. Such re-foresting will assist in making the water-power of some of our streams available by holding back water in times of heavy rainfall and maintaining a steady flow in time of drought.

Those of us who have traveled in the West, saw repeated in Mr. Newell's excellent lantern slides, illustrations of barren land made fertile by irrigation, sights which had been presented to us in traveling. The area occupied by Salt Lake City and vicinity was a desert, until irrigation made it a garden spot, and a traveler through Utah, Idaho, Nevada, Wyoming, etc., becomes wearied with the sage brush, sand and lava lumps until a site is reached where water has been applied to make a veritable oasis in the desert.

We fail to appreciate the immense power which can be obtained from some of our streams until we place side by side such statements as Mr. Newell made concerning the great volume discharged by the Arkansas River, and the immense height through which it falls. With the improved methods of transmitting power, the advance in generators and the interest which is being awakened in forest protection, it would seem that engineers would be called upon in connection with the development and application of water-power so that there will be more business in this line in the next ten years than there has been in the past twenty-five years, and some of the younger members of the Club may find this specialty worthy of their attention.

Mr. Rudolph Hering.—Mr. President, I desire to express my gratification in hearing what excellent hydraulic work is now being done by the Geological Survey. It is certainly a field that needed investigation. Twenty-three years ago I was myself a member of that Survey, and in the State of Idaho, while we were lying in camp waiting for supplies, I endeavored to tell some farmers located there, about how much water they might get from a certain stream, and what power they could have. It struck me then that it would be a very good thing if the United States would officially extend that kind of information to the settlers; and I am very much interested to hear how careful the work is being done. Of course, it is not as accurate as we would do it in the East, but it would be unwise now to attempt greater accuracy. It is better to extend the investigations over a larger territory, with approximate results, than to confine them to fewer streams, but with more accuracy.

I would also like to say how much pleased I am that the

Bureau of Water is continuing the water investigations under the able direction of Mr. Codman, because there are few localities in the United States where to-day there are better means of determining the relationship between rainfall and stream-flow with such a high degree of accuracy, regarding the relation of the run-off to the slope of the territory, and to the physical condition of its surface. The original surveys made under the direction of Col. Ludlow were in great detail, and pains were taken also to record the extent of woodland and the rocky territory, buildings and road surfaces, so that, among other things, it was possible to ascertain the degree of permeability of the surface.

VII.

ELECTRIC HEATING.

By J. Chester Wilson, Active Member of the Club.

Read April 20, 1895.

Cold transmission of electric energy means the economical transfer of power.

The heating of any part of the system of wires or other conductors, whether in the battery or the mechanical generator from which it starts, or elsewhere, is waste or loss in proportion as the temperature is raised in the various mediums of transfer.

A conducting medium requires to be no less in capacity than its necessities, to carry electricity with the highest economy.

It is therefore apparent that if cold transmission is economy, to obtain heat is at expense (not to say, however, that even cold transmission is free from cost, in loss, and a small amount of heat).

It is likewise apparent that if freest transmission is freest of heat, that impediment or resistance to transmission is a method for obtaining heat.

This fact is utilized where heat is required.

The proportion of heat developed is related exactly to the blockade to the free transfer of electric energy; the blockade therefore may be designed in exact proportion as to the heat desired at any local point.

Joule found the number of units of heat developed in a conductor is proportional:

I. To its resistance;

II. To the square of the strength of the current;

III. To the time the current lasts.

The blockade to flow, better known as resistance in the circuit, may be placed just where the effect is desired.

The commonest illustration, and by the brilliancy of its effects the most striking, is the incandescent lamp.

Modern invention has so perfected the system of lighting, that an entire installation may, to the casual observer, be cold through-

out every appliance from the power belt to the last lamp, except in the little wicks themselves.

The little lamp has heat in it, in spite of the old name given it, "light without heat."

The ordinary incandescent lamp itself is utilized now as a heater of small capacity and requirement.

One may buy a tea-pot, constructed to enclose under the tea-vessel, an 8-candlepower lamp, which is sufficient to keep up a temperature agreeable to the afternoon-tea server. Or a 16-candle lamp will keep boiling water at the boiling point, or in the same utensil a 50-candle lamp will raise two or three pints of water to the boiling point in twenty-five minutes.

This use of the small electric lamp is simply an effort to obtain somthing unique and exquisitely cleanly for such a purpose.

We have all observed that waste or radiated heat is exceedingly small compared with older forms of lamps, such as that of oil and gas.

In 16-candle power, while the incandescent lamp will raise 14 pounds of water 10 degrees F. in the heat given off in an hour's lighting, a kerosene argand burner will raise to the same degree 331 pounds, or nearly twenty-four times as much.

Certainly the incandescent-lamp filament cannot be looked upon as a factor in designing an article for commercial heating. Its cost as a heater would many times exceed the usual methods.

It may be observed in passing: Much has been done in the search for a cold light, and some surprising results have been attained in the use of vacuum tubes, giving many hundred times the efficiency of the common incandescent lamp. In it the electric alternating current of high frequency is used.

So that, as the glow-lamp, hot as it is, was welcomed as a "light without heat," we may not expect too much, to look forward to the vacuum tube and the electric alternating current for a greater stride towards an absolutely "cold light."

The temperature rises quickly in the incandescent-lamp wick because of its fineness and short length. The nature of the resisting medium has to do with the rise of temperature. Platinum was early used for lamp wicks; its nature differs greatly from many metals as a conductor of electric current and likewise

as a conductor of heat. Comparing it with silver; the capacity of silver for heat is twice as great, but the specific resistance of platinum, to flow of current, is nearly seven times as great as silver.

The rise of temperature, therefore, as between these two metals under similar conditions, would be about 12 to 1 in favor of platinum.

Therefore, in selecting a resisting medium for local heat effects, one must use wisdom, being governed by efficiency of metals and with a proper view to their cost, etc., etc.

We have referred to the incandescent lamp as an illustration of heating effect, and shall later use the principle set forth by it in other connections.

The electric arc, however, furnishes us the highest type of electric fire, with which we have any familiarity. Just here we must express the wish that our Club may soon have, as a part of our paraphernalia for experimental purposes, all the varieties of electric current "on tap;" for had we access to an arc circuit now, we might place upon the screen the arc and, at our leisure, study it. We would find in it "a thing of beauty" and an instructive physical phenomenon.

As early as 1878 it was my pleasure to talk to a vast audience, with a projection of the arc on the screen, where the $\frac{3}{4}$-inch carbons were shown 16 to 20 inches across.

It was a wonder then as we looked at the ebullition of the carbon and speculated as to its power, and prophesied about its future.

Since then we have been instructed concerning the steady habits and constant principles of the artificial orb.

Doubtless the greatest heat obtained by electric energy is that developed in the electric arc.

While the name, which Davy gave to the stream of pulverulent carbon projected across the space between the carbon rods, has attached itself to all lamps of its class, it must not be understood that the arc itself is the source of the illumination or the seat of the enormous heat (the chief cause of light).

When continuous currents are used, the light is chiefly due to the intense heat on the surface of the positive carbon, which is heated and wasted about twice as fast as the negative.

The negative carbon has also great heat, and consequently emits some light. In the positive carbon the white heat of the crater may be obtained by a smaller electric current than 5 to 10 amperes, and 40 or 50 volts, usually employed. Both Violle and Thompson agree that increasing the voltage or current beyond the point of volatilization of the carbon does not increase the color or intrinsic brilliancy of the light, a uniform lightness of the crater surface is maintained in pure carbon, even should there be variation in the potential.

An increase current and pressure will burn away by oxidation more carbon and lengthen the arc and widen the crater surface, from which the increased brilliancy is emitted.

Violle attempted to measure the temperature of the arc, and has decided it is about 3,500° C., which is simply the point of volatilization of carbon.

In this intense heat, platinum and gold are vaporized readily, and the diamond as readily fused. The first use of the arc was not for its lighting power, but for heating.

It is fifty years since Cowles first used the heat of the arc in a reduction furnace for obtaining aluminum copper alloys. He depended upon the heating effect alone and procured only alloys. His furnace was simple. Later workers use both the heating effect and electrolytic effect.

Herault uses another form wherein one pole terminates in the usual carbon rod, while the other is shaped to be a crucible of carbon; 12,000 to 15,000 amperes of current are used, and a low voltage.

The charming feature of an electric furnace is the advantage of being able to introduce the necessary heat to the inside, while the chamber is hermetically sealed, and utilize the heat there.

Combustion of foreign material in large quantities, as the necessity is in other furnaces, is eliminated to the advantage of the ore or metal being treated, preserving its purity after being reached.

At the present time the Patent Office is receiving a great many applications for furnaces, especially wherein the electrolytic effect is taken advantage of, and a variety of chemicals are recited as being effective for various operations.

But a few years ago aluminum was sold at $100 per pound; now it is being utilized in the manufacture of a vast variety of things, wherein there is a profit at 75 cents per pound. (The market value of the metal runs to-day from 45 cents for least pure up to 65 and 70 cents per pound for the best.)

In domestic heating it is found the commercial efficiency of the coal cooking range is as low as between 3 and 6 per cent. (*Electrical Engineer*, March 7, 1894).

Another investigator (*London Society of Engineers*, November 6, 1893) gives it from actual experiment 4 per cent. and shows but 1 pound of coal in 27 is actually effective.

Hedaway says (*Electrical Engineer*, March 7, 1894) the heat efficiency of the average moderate sized central station is about 6 per cent., and this is a sufficient margin to warrant the use of electricity as a source of heat in domestic life. This low efficiency is based on figures of no advantage to this branch of commerce, and would of course be improved with apparatus of proper size and planned for higher working economy where apparatus and tools are all more regularly employed.

The lamp rates, now generally prevailing, will preclude this branch, but a heat rate which will be evolved as a demand redesigns central stations, will bring about this model heating. The cleanliness, regularity, convenience and healthfulness will down many of the objections to higher rates, especially in earliest stages of its introduction.

The power rates of the Edison central station companies, with the discounts allowed to large users, is equal to 5 cents per horse-power hour. In the Electric Kitchen in New York, on an eleven weeks' trial, at the 5-cent rate per horse-power hour, an average of 97 persons were served at an average cost of 2.5 cents each for the heat.

Every form of industrial work is undergoing change in this particular.

A 7-pound electric laundry iron requires about 330 watts for a far more efficient and economical service that can be otherwise had, that is with the old furnace of coal or gas. In such a service more elements enter into cost or economy than are at first appreciated. In electric laundering the continued readiness by con-

stant temperature, avoidance of overheated room for operators, and the all-important matters of cleanliness and safety must be considered.

I here exhibit a laundry iron which has been torn apart for your inspection. The current passes through the coils contained within and offers such resistance that sufficient heat is generated for the work. The mechanical design is worthy of an inspection.

These are practical and are largely in use in this city and elsewhere. I have just inspected their working in a clothing house, where I was told they are there to stay and more are wanted.

Another appliance meeting with popular favor is the electric glue-pot; one is here exhibited and will be admired upon inspection.

[Note.—Wm. Mann Co. has a large battery of these in the bindery and praises their efficiency.]

On the usual 110-volt incandescent-light circuit about 2 amperes are used in heating and maintaining working conditions, being equivalent to about two glow lamps.

Another happy combination wherein the arc is used for an industrial tool is found, and here exhibited, in the electric soldering iron.

Through the wooden handle passes the current by flexible conductors, one side of the current reaching the soldering point by way of a central carbon rod, which is adjusted by the back screw to touch or be withdrawn from contact with the inner part of the copper tip piece, which is connected with the inner side of the current by the sheathing tube.

This also is a practical tool. It requires 3 to 7 amperes, and on a 110-volt circuit a resistance is connected in of about 17 ohms.

Probably the greatest attention in heating, looking to personal comfort, has been given to passenger street-car work.

Here the application is greatly simplified by the presence on the car of the needed source, in the greatest convenience.

Connections from the line may be had by simply tapping it on its way to the motor and with the coils of properly regulated

resistance, to develop the needed amount of heat, placed in position to interfere in no way with the seating.

Usually the space under the seats is utilized, and in some forms of heater the space below the rolled edge of the seat and on the face of the seat front is sufficient. Others are designed to replace the panel and be suspended under the seat.

They are usually constructed to be brought to the temperature wished with about 5 to 9 amperes of current, depending, of course, on 500 volts electromotive force.

As to cost, one expert of the Edison Company has published the figures of a series of careful tests. The running expenses are from 12 cents to 18 cents per car day.

He also states for comparison that car stoves cost 20 to 35 cents, or about double.

DISCUSSION.

Mr. James Christie.—I had occasion recently to investigate the cost of car heating by the current. The cars were the ordinary 16-foot bodies, each having four Burton heaters under the seats, as described by Mr. Wilson. The heaters are connected in series, each having a resistance of 35 ohms. These required for each car $3\frac{1}{2}$ amperes of the 500 volt current. Allowing for the usual losses, this can be traced back to an equivalent of three horse-power per car—at the station engine—or in the case under consideration, to 12 pounds of anthracite pea coal per car per hour at the boilers. The value of this fuel was 1.3 cents in the fire-room. Charging this item with its share of the general expense of labor and maintenance, made the cost of heating the small cars about $1\frac{1}{2}$ cents per car per hour.

Mr. George S. Webster.—I would like to ask Mr. Wilson whether the heating of cars by electricity may be considered entirely successful. Is not a good deal of trouble experienced on account of running the heater too hot at times, even to such an extent as to set fire to ladies' dresses, and in other cases of running down to such an extent that the heat becomes insufficient?

Mr. Wilson.—That is one of the troubles and might be looked after a little more carefully by the "man at the wheel." The wire switches should be of such a type that the heat could be

easily reduced, because in some parts of the line under certain conditions of the traffic, the heaters would probably get a little more charge than at other parts. Just what is needed in these things is of interest, and there will be accidents until the switches are a little more elastic, and give a greater opportunity of cutting off, through resistance, or cutting down the coils. The switches that are now used are intended to reduce to two coils in a car equipped with six; another switch to put in four and another to put in six; with the proper attention there would be no occasion for complaint.

Probably some companies constructing heater systems for cars have not used all the wisdom there is on the subject, in the matter of placing the heaters or for their control.

Mr. Carl Hering.—A theater in London has recently been equipped with electric heaters. It is said that the expense in this case is no greater than that of heating by any other means. The theater is required to be heated only a few hours during the day. The conditions are therefore particularly favorable for heating by electricity. It is beyond question that electric heating has many advantages over all other forms of heat. It is merely a matter of cost. When electricity becomes cheap enough, I have no doubt that the present form of heating will be almost wholly abandoned. Electric heat can be regulated with such nicety that economy is possible with this system that with other systems cannot be realized. I think that wherever there has been trouble in the heating of railway cars electrically, as has been stated, it is due to the fact that the apparatus was not properly arranged. There is no reason whatever why there should be the slightest difficulty about regulating the electric heaters in trolley cars.

Prof. H. W. Spangler.—In reference to the theater referred to by Mr. Hering, I have inferred from what I have read, that it was in use during the summer. I cannot conceive how such a place can be heated and lighted at the same time. The idea of putting an electric heater in a combination of that kind seems to me to be at variance with common sense. It would be all right during the summer, but I cannot understand how it could give satisfactory results during the winter.

Mr. Hering.—I think Professor Spangler is mistaken in regard to this theater being heated during the summer. The description appeared in the papers some time this winter, and I think the theater has been heated in this way during the whole of the past winter.

Prof. L. F. Rondinella.—Is the electricity supplied from the street main?

Mr. Hering.—Yes.

Prof. Rondinella.—In that case Professor Spangler's remarks would not apply.

Mr. Pike.—The question of heating cars electrically is one which is apparently very easy of solution; but when you consider cities situated as those of northern New York or farther north, the question becomes different and more serious. The figures given by Mr. Christie, of three amperes per car, are not far from correct for cities farther south. Now the number of horse-power used per car varies somewhere from 6 to 8 or 9, according to the nature of road-bed and traffic. For instance, three or four years ago, in Boston, the amount of territory covered, and the nature of it, was such that the average horse-power per car was about 6, that is, it would require between one-third and one-half as much power for the heaters as to run the cars. The heaters do no more than take the chill off. I do not believe, therefore, that any railroad company operating in the northern cities either does attempt or would attempt to really heat its cars electrically; but in cities like Philadelphia, Washington, Baltimore and other cities, the system becomes feasible and much more advantageous than coal-stove heating.

Mr. James Christie.—We find electric heaters in the street cars of Montreal and Ottawa, probably the coldest regions where electric cars are operated. In the latter city an abundant water-power allows the companies to offer inducements for the use of current, for domestic culinary purposes. One gallon water heaters, 50 cents per week; for rent of heater and use of current, or 25 cents per month rental; and current by meter, $\frac{8}{10}$ cents per ampere-hour. Stoves owned by consumer, $\frac{1}{2}$ cent per ampere-hour.

Mr. George M. Sinclair.—I understand that one horse-power

can be supplied for ten hours per day at an expense of $25.00 per year. At that rate the receipts of a single car for two or three days would be sufficient to heat it for a year.

Mr. A. Falkenau: The Power Company at Niagara is reported to have recently made an offer to furnish power at Buffalo at an annual charge of $22.00 per horse-power per twenty-four hours.

(The following written discussion was subsequently contributed by Mr. Carl Hering.)

In the discussion of Mr. Wilson's recent paper I remarked that the Vaudeville Theater, in London, was recently equipped with electric heaters, but at that time I could give no further information.

Those interested will find a brief description of the plant, with illustrations of the heaters, in the London *Electrical Engineer*, March 8, 1895, page 285, and in the London *Electrical Review*, March 8, page 293.

From this it appears that there are six box radiators on either side of the theater, and twelve attached to the partition in front of the orchestra; there are four large portable radiators arranged for use in different parts of the theater; the average temperature of the theater is about 60°; arrangements are now being made to heat the stage in the same manner. The current actually used for warming the auditorium is 90 amperes and 110 volts, which, at 8 cents per kilowatt-hour, is 75 cents per hour, which, for an evening of four hours, amounts to $3.00. One of the great advantages is perfect regulation and the conveniences attending the system. From a comparison with a hot-water system, it is claimed that the electrical system will probably cost considerably less to maintain. The cost of installing the electric heating apparatus was found to be about the same as that for hot-water heating; the advantages of the former, however, are said to be so great that they would have justified even a higher price. Electrical heaters are on trial at several other theaters and public buildings, in some of which they are used for temporary assistance in extra cold weather. The whole installation was completed, at a few hours' notice, early in January of this winter.

In connection with the economy of electrical heating, the fol-

lowing from the recent paper of Mr. Crompton (abstracted in the *Electrical World*, May 18, page 587) may be of interest. He claims that the opinions recently stated, that electrical heating for cooking is too expensive to become general, are based on an insufficient knowledge of the economy of cooking as generally carried on; the smallness of the results obtained by the electrical method are astonishing; the amount of heat actually utilized in cooking on the ordinary stove was found by experiment to be not more than 2 per cent.; the enormous waste, except in boiling and stewing, being due to the fact that radiated heat is used; in an electrical oven fully 90 per cent. of the heat may be used, which represents 4.5 per cent. of the whole energy of the coal, which is therefore twice as economical as the ordinary oven; evidently it does not follow that therefore it would be more economical in a private house to generate electricity for cooking purposes only. He believes that in a few years the majority of the consumers of electric light will do all their cooking by electrical means, using solid fuel only for boiling purposes. CARL HERING.

VIII.

COFFER-DAMS.

By William H. Dechant, Active Member of the Club.

Read May 4, 1895.

Crib-work coffer-dams have long been used by Messrs. James F. and Edwin F. Smith, Engineers-in-Charge of the Canals of the Philadelphia and Reading Railroad Co.

Formerly such coffer-dams were fastened together or built up entirely with driven bolts, commonly called rag bolts or dock bolts, usually made of $\frac{3}{4}$-inch square iron, but later the plan about to be described has been used, giving excellent results.

A few of the principal advantages of crib-work coffer-dams over the frequently used clay puddled dams are:

First.—A crib-work coffer-dam resting on solid bottom filled with stone forms a stable structure, able to withstand the destructive effects of freshets even though they should flow over the top of the dam, while a clay-filled dam under such conditions would likely have its filling churned or washed out and the dam destroyed.

Second.—A crib-work coffer-dam properly sheet-piled and puddled on the outside can be made tighter than a clay-filled dam, because the sheet-piling around the crib dam can be solid and continuous.

The tie-rods usually placed between the two sides of a clay-filled dam seriously interfere with tight sheet-piling and also cause much trouble on account of settlement of the puddling, which leaves a small opening beneath the tie-rod, along which the water finds its way and soon tears out a large opening across and through the puddle dam.

Outside puddling is more effective than a vertical wall of puddling, occupying the space between two vertical lines of sheet-piling, for the reason that it is easily applied to the point of greatest danger from leakage, namely, the bottom of the sheet-piling. It is cheaper because a small quantity only is required.

The body of puddling is pressed into the wedge-shaped corner,

its greatest thickness in the line of pressure being about opposite this most vulnerable point, outside puddling is also to be preferred on account of the unobstructed and unlimited opportunity to close up rock seams or loose material through which the water might find its way under and into the coffer-dam. If the coffer-dam is placed in a strong current, coarser material, gravel or stones mixed with the puddling will usually prevent washing, but if not there are other simple expedients for breaking the current.

Another advantage is in the character of the puddle material that can be used outside a crib-dam as compared with that necessary for a clay-filled dam.

Puddle used in a clay-filled dam is all right as long as the water cannot find a way through it, but it is treacherous if the slightest path for the water occurs, because the cohesive character of clay makes it possible for such an opening to enlarge and form a tunnel for the passage of the water without causing the top of the puddling to fall, whereas in the outside puddling coarser material can be used, which has no such cohesive quality, and which can be covered with layers of finer material to tighten it; the whole tendency being as soon as the water is drawn from the inside of the coffer-dam to force smaller particles into such puddling, thus compacting and tightening it.

Third.—A crib coffer-dam clamped together can be more economically constructed and more completely removed by simpler methods than the clay-filled dam, and the material used in the construction of it almost wholly recovered for further use. This matter of easy and complete removal is of great importance in most cases, so as not to reduce the cross-sectional area of the stream more than is absolutely necessary.

The accompanying plan and sections show the simple construction, a brief description of the operation is as follows:

The first requisite is an accurate set of soundings along the foundation lines of the crib.

Next determining the size of crib and timbers necessary, the latter should all be sawed of uniform dimensions.

Next the bottom parts of the crib must be fastened together upside down, so that the bottom can be blocked up and cut out

to closely fit the rock or solid matter upon which the crib is to rest.

The crib bottom being thus prepared and properly launched the first course of ties and floor are placed upon it as shown; a sufficient number of this first course of ties must be fastened to the crib bottom by means of driven dock or rag bolts, the balance are held in position by nails or spikes toed through the corners of the timber.

The clamp ties are properly bored to receive the screw bolts and the bolts are fixed in them so that they cannot turn or drop. The balance of the crib-timbers are then simply laid in place and temporarily held so by nails, toed through their corners; the weight of the added timber gradually submerging the crib-work until it has reached its proper height, when the top clamp-ties are placed and the bolts all tightly screwed down, clamping the whole crib firmly together.

Next the crib is filled with stones to sink it properly to its place and also to amply hold it in its position against any force likely to disturb it. The sheet-piling around the outside is then applied. This is a very important part of the work and must be carefully done.

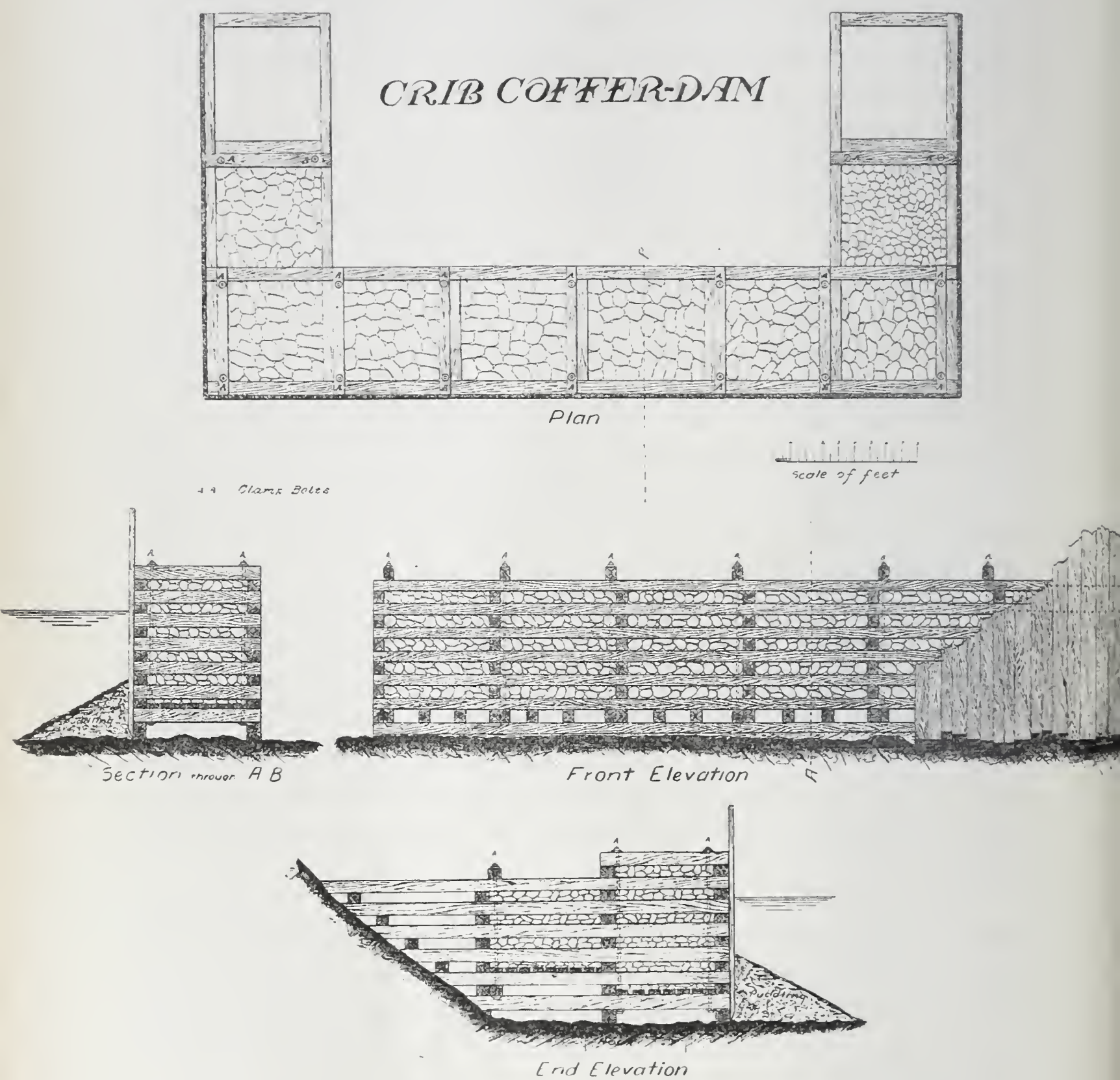
The sheet-piling plank should be dry and carefully jointed (machine-jointed first if possible and afterwards hand-jointed), perfectly straight and true, leaving the side resting against the crib slightly widest at the edges so that they shall be tightest at their inner edge, and form a minute wedge-shaped opening into which the small particles in muddy water may be drawn and assist in making the whole work more thoroughly water-tight.

The sheet-piling plank must also be carefully fitted to the hard bottom upon which the coffer-dam stands, the planks must be pointed and driven down well, then taken up and the points carved out to more closely fit the bottom, as shown by the bruises on its edges, this must be repeated until the point of the plank closely fits the bottom.

During the driving of the plank it must be held tightly against the last one driven by long point bars thrust into the timbers of the crib and used as a pry against the plank being driven, they

must be spiked fast to the crib as low down as possible after they are thoroughly adjusted and driven.

If the sheet-piling has been properly done the puddling at the



bottom, which comes next, will not require much material, labor or trouble.

Experience proves, that after such a coffer-dam is pumped out, the longer it is used, the tighter it becomes.

When the coffer-dam is to be removed the stone filling is taken out before the water is let into the enclosure, a sufficient quantity being piled on platforms above water surface to hold the crib down until this operation is complete.

After the stone filling has been removed the sheet-piling is taken off; the balance of the stones are then taken off the crib and it is allowed to rise, the screw clamps are removed and the whole coffer-dam is easily taken apart, all the timbers being practically uninjured.

The small quantity of puddling remaining after taking up the dam, if it offers any serious obstruction, can be scooped out by handscoops.

A good example of crib coffers, *clamped together with long screw bolts* instead of being bolted course to course of timber, with dock bolts, were those lately used for the piers of the Highway Bridge, now building at the Falls of Schuylkill.

DISCUSSION.

Mr. John C. Trautwine, Jr.—In sounding the rock bottom, how far apart are the soundings taken?

Mr. Dechant.—It depends very much on the character of the bottom. We usually take them about two feet apart. In taking soundings for coffer-dams, it is advisable to make the float correspond in size and shape with the coffer-dam.

Mr. C. H. Ott.—To what depths are these dams sunk?

Mr. Dechant.—The greatest depth that I have known is about twelve or fourteen feet. The limiting depth is that at which the plank can be properly handled.

Mr. Edwin F. Smith.—The theory of the coffer-dam, as I understand it, is to put in a stream a mass of material, enclosing the space to be freed from water, of sufficient weight to resist the pressure of the water on the outside after the dam shall have been pumped out. The enclosure must also be made as nearly as possible water-tight. In the case of the Falls of Schuylkill Highway Bridge, the coffer-dam was about 78 feet long, by 44 or 46 feet wide, inside dimensions, and was in 12 to 14 feet of water. Now, all that is wanted in such a case is to surround the space to be occupied by the pier with a water-tight mass of sufficient

weight to resist, unaided, the pressure of that depth of water on the outside. It stands to reason that if you have crib-work filled with stone, or any other form of enclosure that will resist the pressure of the water on the outside, and can plank that structure so as to make it water-tight, you will then have a coffer-dam that will answer the purpose without the use of clay puddle. If there is rock bottom, it is practicable to so fit the planking to the inequalities of the surface, as to be nearly water-tight, after which concrete or gravel will complete the joint.

It is better to avoid clay puddling as much as possible in the structure to be water-tight. Clay is always treacherous; it is almost impossible to make any structure water-tight if we depend upon clay alone, whereas it is very easy to make it water-tight with gravel with a small proportion of clay in it, if you understand the proper mixture, and it is very easy to do it even with sand alone if you protect the sand from washing away. Therefore, when you have planked the side of your crib in the manner described by Mr. Dechant, all that remains to be done is to put a filling of such material at the bottom of the planking as will close any crevices and prevent leakage. At the railroad bridge usually called the Baltimore & Ohio bridge, at the Falls of the Schuylkill, we had one of these dams in use in eighteen feet of water; the bottom was of rock, full of seams, and it was very easily made tight by dumping heavy gravel with a covering of mud dredged from the bottom of the river. It made a very tight dam, it being necessary to pump only about three or four minutes out of every ten minutes to keep it clear of water. A crib makes a very safe coffer-dam, and one in which workmen need not be afraid to work. On the other hand a framed dam, filled with puddling between two lines of sheet-piling is unsafe.

A crib-dam, such as Mr. Dechant describes, will not spring a leak suddenly, as a clay dam may, and when they do leak, as occasionally happens at the bottom, you know just where to look for it. In the case of the coffers used at the Falls of Schuylkill, the diver was able to go entirely under the crib, as far out as the sheet-piling, to take measurements and to adjust the planking, and in some cases to ascertain the cause of leakage. The rock bottom in that case was so bad that it was at times impossible to

drive the sheet-piling so that they would set together at the bottom, and we therefore had to resort to double sheet-piling in some places. The saving of timber makes this modification of the crib coffer-dam by Mr. Dechant a valuable one. This he has effected by putting the dam together with long screw-bolts, and it is a great improvement in the construction of crib coffer-dams. In the case of the coffers at Falls of Schuylkill Highway Bridge part of the timber was used twice. It was used for two piers, and after the completion of the work was entirely removed from the bottom of the river, and is now on hand for other work, the timber being almost as good as new.

Mr. Trautwine.—The remarks thus far have been mainly concerning rock bottom. I would like to ask what modifications would be made in the case of a soft bottom.

Mr. Dechant.—It is always better in putting in coffer-dams to remove the soft material if you can; but if you cannot, it is a saving in one way to have a mud bottom—it is usually very level, thus avoiding many soundings and shaping up the bottom of the coffer-dam. The coffer-dam will sink into the mud, its weight eventually carrying it to a certain point, and the bottom and joints of the sheet-piling plank driven down through the mud will likely be almost tight without further puddling, so that as far as leakage is concerned, a mud bottom is not an unfavorable condition, the greatest difficulty with a mud bottom being the unstable support of the coffer-dam during the interior excavation, but the transverse strength of a crib-clamped coffer-dam makes it more susceptible of being securely shored than any other.

Mr. Geo. S. Webster.—In constructing the foundations for the Falls Bridge, in this city, over the Schuylkill, no difficulty arose in connection with the masonry. It was found that the water could be kept out of the coffer-dam with very little work.

Mr. Dechant.—There is one point that Mr. Smith touched upon which is a very important one, namely, the great strength of crib coffer-dams. The clay-filled dam is weak, but crib-dams are very strong. If properly braced, the work can be carried directly to the edge of the dam, and even underneath it if necessary.

Mr. Smith.—In removing rock obstructions from Fairmount pool, I remember that we used coffer-dams 48 by 32 feet, and we excavated the rock bottom from the whole of the surface up to the sheet-piling. When blasting, the rock was removed even underneath the crib. This shows to what an extent the work can sometimes be carried on under a coffer-dam, thereby saving a corresponding area in the dam.

Mr. Webster.—In the construction of the Walnut Street Bridge, use was made of the Robinson patent. The contractors volunteered to use that form of coffer-dam. It was barrel-shaped in form, with hoops on the outside made of railroad iron. The idea was that being circular in section the pressure of the water would be better resisted. The experiment proved unsuccessful. The coffer-dams referred to collapsed and the rectangular crib was subsequently used.

Mr. Robert W. Lesley.—Some effort was made in the use of the Robinson coffer-dam at Newport, Ohio, and after a great many experiments it ended in failure.

Mr. Webster.—So far as our experience has gone, the crib-dam has been the most successful.

IX.

RAILWAY CONSTRUCTION ON THE PERUVIAN ANDES.

By James R. Maxwell.

Read May 4, 1895.

The Republic of Peru is situated between parallels 3 and 18 south, and meridians 4 west and 8 east, reckoned from Washington. Lima, the capital, is almost due south from Washington, as there is only about three minutes difference in time. The average breadth of Peru, east and west is about 450 miles; length north and south about 1,000 miles; coast line on the Pacific, 1,700 miles; area, 12,000 square miles; estimated population, 3,000,000.

The larger portion (probably 70 per cent.) are Indians; then the mixed races, say 20 per cent.; the rest are whites, mostly of Spanish descent. The Indians differ from those generally found in this country in appearance, language and mode of life. None of them lives by hunting; all work, and lately have furnished the unskilled labor for building the roads.

The principal cities are Lima, 101,000 population; Callao, its seaport, and the principal port of the country, 34,000; Arequipa, the largest city in the south, has 29,000, and Cuzco, the ancient capital of the Incas, is said to have 18,000. The country has so few factories, taking them altogether, that less than one-half of 1 per cent. of the population is engaged in them, and it is safe to say that 99 per cent. are farmers or shepherds.

The Andes range extends through the country from north to south; its crest and the coast line being roughly parallel, and from 75 to 150 miles apart. At the smaller distance the western mountain slopes reach the coast; when further off there are intermediate plains that have a slope of not less than 2 per cent. In three instances the range divides and forms interior basins, as shown; first, in the drainage flowing into Lake Titicaca; second, where the river breaks through to the west and flows into the Pacific, near Chimbote; and third, where the Tungurangua, running in the opposite direction, flows to the Amazon. These ranges

are high; the lowest passes in them are over 14,000 feet above sea level, while their peaks are much higher. Parinicota is over 20,000 feet; Misti, an extinct volcano, 19,000 feet; Ubina is nearly as high—this is still smoking. Further north is a beautiful snow-capped peak, known as the Alta de Peru, which is probably the highest mountain in the country.

On the coast there is practically no rain, but precipitation increases in volume toward the top of the mountain, and still more further east. There are no trees on the mountain slopes; a few, alders and willows, grow near the streams, but none is found above an altitude of 12,000 feet. Near the coast some scattering trees, like the honey-locust, are found, but none that will furnish lumber. The mountains are bare most of the year. During the rainy season, our winter months, there are heavy fogs that furnish enough moisture for a scant vegetation for a few months on the low grounds below the rainy belt. Near the summit, and all down the eastern slope of the range, a short grass grows while it has moisture, and then forms a natural hay. In low altitudes the land is very fertile, where it can be watered, and as all climates are found on these mountains, it is possible for any plant to be grown. The rain-fall being greater on the eastern slope, the streams there are much larger, and the slope being less abrupt, the valleys are broader, and a much greater proportion of the country will support life. On the western slope the population is confined to the valleys in which there are flowing streams, or enough water to be taken to some adjoining bench land.

In passing along the coast in a steamer, little cultivation can be seen, and the general aspect of the country is that of a desert. Fuel is very scarce in the high altitudes, and the people use the dried droppings of animals for that purpose. The horned cattle, sheep and llamas, furnish most of it. Stakes make good firewood, and the engineers were often annoyed at first by having them stolen, sometimes even before the level-party caught up.

There are no public roads in the county on which vehicles can be used, except in the vicinity of Lima, and more particularly between that city and Callao. The Incas had roads made all over that part of South America that they controlled, but they

were only for foot passengers and llamas. These roads were generally well laid out for grade, but in other respects the location was often bad. For instance, there is one far down on the eastern slope, on the right side of a small valley which has a fall of about ten per cent. The road descends about half as fast, and is soon left high above the bottom on a steep side-hill. When it came to a ravine it zigzags down to the bottom, and then ascends the other side of this hollow in the same manner. The barometer showed a thousand feet rise and fall in one of these zigzags. The road was well graded, mostly in a soft rock cutting. This is also mentioned to show that the Incas understood the way to use switchbacks.

On another road near Cuzco the ascent of a hill was made with long steps; each one being from six to eight feet long, and one foot in height. These were paved in outline on the tread. The rise was solid work.

The Spaniards did not make much improvement, if any, on the roads; but they did build some good stone bridges, over the larger streams. On the small ones some of those built by the Indians on the same plans that their ancestors used, are yet to be seen. One a rude form of cantilever, another a suspension bridge for foot passengers, made of small sticks, plaited together to form the cables. There were three strands, each about six inches in diameter. The sticks seemed to be about four feet long, and half an inch in diameter at the butt. From Lima to Callao there is a good wagon road, but about all the work that was ever done, was to fence it in, and build some small bridges over the acequias. These were all the ways of communicating with the interior, until about the middle of this century, when the first railroad was built, a short line from Callao to Lima, seven and a half miles long. The work was very light, and the total cost was probably not over $150,000, for building and equipment. It was used for passengers only and was very profitable. It was sold for $800,000, to an English company which capitalized it at £500,000, and paid a six per cent. dividend on that amount. Under the same concession it built another light line, eight miles long, from Lima to Chorillos, to reach this summer resort and bathing place on the Pacific Ocean.

Late in the sixties the Peruvians saw how the Chileans were opening up their country with railroads, and became anxious to develop their own in the same manner. The Government had a large revenue from the sale of guano, of which it had a monopoly, and easily floated a loan in England, and organized a system of Public Works. A number of roads was projected; several of which were to cross the Andes, but most were only local, reaching in from the coast to some productive locality.

The character of the country is such, that but few of these roads will ever become a system, or form a junction with any other; until getting far down on the eastern slope of the Andes. The mountain country is very rugged. The valleys that start from the main range are deep chasms; always very narrow on the western slope. The ridges between them are high and steep and much broken up on the sides. Where the mountains are the furthest from the coast there is a bench; usually from two hundred to three hundred feet above the sea, and rising gradually to the foot-hills. This is cut up with deep ravines, running down to the sea. The sides of these cañons are precipitous, as there is neither rain nor frost to wear them down. A survey made to ascertain the expense of extending the railroad from Mollendo to Islay—only six miles along the coast—showed that it would cost $1,500,000.

On the eastern side of the Andes, the descent is much easier, as the valleys do not fall so fast and are generally wider. But the intervening ridges rise for several thousand feet, and keep their relative height far down into the lower country, rendering a north or south connection impracticable on account of the cost of building and operating. The Board of Public Works was composed of engineers and reported to the Secretary of the Treasury. Some of these gentlemen were educated in this country, but most of them studied in Europe. This Board fixed the standards—the maximum rates of grade, the minimum radii of curves, the minimum length of tangents, between curves in opposite directions, and the rate of compensation on curves and on construction, the width of the road-bed, the angle of the slopes in cutting, the weight of rails, character of fastenings, size and quality of ties, size and material of stations, length and position

of sidings. Under these conditions, all the details were left to the contractors' engineers, subject to the approval of the Government inspecting engineer of the district, who also approved each monthly estimate. The maximum grade was fixed at four per cent. On curves of 120 meters (the minimum radius allowed) the grade was fixed at three per cent. On curves of 600 meters radius or greater no compensation was required. On curves with radii over 120 meters and less than 600, the rate was made proportional between the limits. The minimum length of tangents on curves turning in opposite directions was made thirty meters. The standard road-bed was 14 feet wide—cuts 16 feet at subgrade —through bridges not less than 14 feet in the clear. Tunnels 15.75 feet at the springing line of the arch, and 18 feet high inside. Minimum thickness of masonry lining, 16 inches. The gauge of most of the roads was 4 feet 8½ inches, but there was one road of a meter gauge and a small one of 3 feet 6 inches. The contracts for most of these roads were let in 1869. At the first letting Mr. Henry Meiggs got all the large roads and some of the small ones, but others of these were let to other parties. In 1872 Mr. Meiggs had contracts amounting to $100,000,000 under way. Most of the small roads were of local character, easily built and of no special interest. The 3 foot 6 inch gauge was on the eastern side of the mountains, at Cerro de Pasco, all the material for which—rails, ties, spikes, locomotives and freight cars—was carried piecemeal over the mountains by mules. The maximum weight of a piece could not exceed 270 pounds and the rails were in 6 feet lengths, weighing 45 pounds per yard. The road of a meter gauge was one that could not cross the mountains nor connect with any other. It started from Chimbote and was to follow up the valley of the Rio Santa to Recuay, 165 miles distant. It has a maximum grade of two per cent. and when finished will be one of the best paying roads in Peru. It was extremely difficult to build, and was not a favored road, so was not pushed with vigor. The difficulty was a cañon, about 70 miles long, where the Rio Santa breaks through the coast range. In places the river flows between vertical rock walls; in one case, at the upper end of the cañon, there is a stretch of seven miles in length that has never been penetrated by man. It is probably not any worse

than a part about half as long, nearer the middle, where there are five tunnels in less than a mile. No person was ever in this box cañon before the railroad men.

One of these tunnels was located and built, both for grade and alignment, by triangulation from the opposite side of the river. It had a curve at both ends, with a tangent between. It was worked at both ends, and through three adits at the same time, and when the headings met, the line and grade were very good. It cost more to make the preliminary mule-trail per mile for this road than it does to grade a railroad in ordinary country. This trail was generally on benches from 20 to 30 feet above the river, but the benches were short, and then the trail would climb the hill, cross the river or stick on the rocks. It might rise 1,000 feet, cross the stream on suspension bridges made by laying the floor on the lower cables, with other cables on each side about four feet higher, to serve as a side-rail, or it might cling to sloping rocks, by means of iron pins set in holes drilled in the rock, with poles laid on these, and dry walls built up, which were leveled up behind with earth or small stones to form the road. Track was laid on about 67 miles, but the extremely high freshets about 1884, broke the road in many places in the cañon, so that not over half of it is now in operation.

The southern system, which is the largest in Peru (see profile), consists of the road from Mollendo to Arequipa, 107 miles long, Arequipa to Puno 218 miles, and the one projected from Juliaca to Cuzco 210 miles, but which is only finished to Sicuani, 112 miles. Considerable work was done on the Cuzco end.

The first road is level for 9 miles, then rises 22 feet in four miles, and over 3,200 feet in the next twenty miles, by a very well located development. For the first 76 miles of this road there was no water near it. This was hauled in tanks, and during construction cost over half a million dollars.

There is a pipe line now 84 miles long, that furnishes water for the lower part of the line and the port of Mollendo. There is over 6,000 feet difference in the elevation of the ends of this pipe.

On the second road, and about 26 miles from Arequipa, another fine development is made. This line crosses the sum-

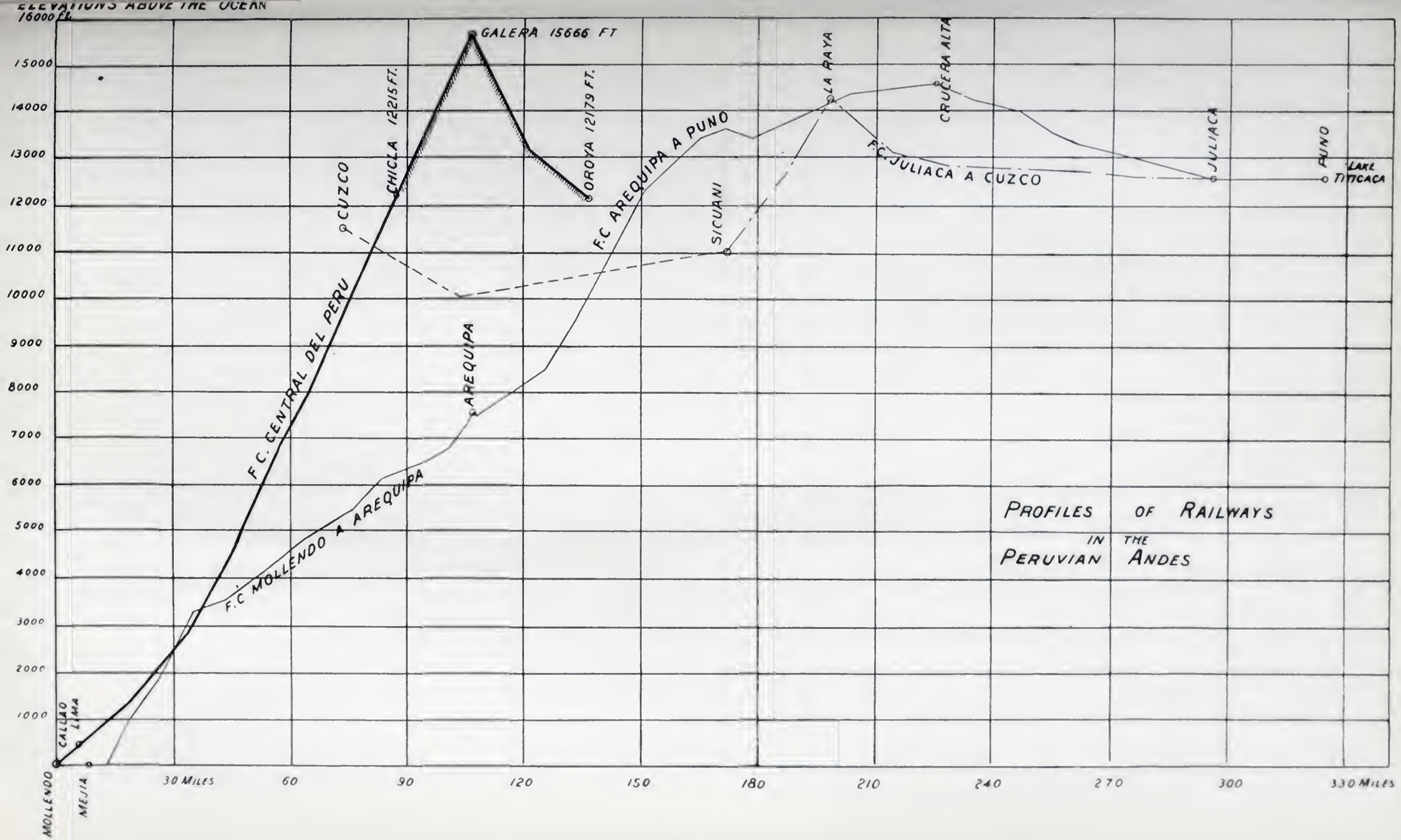

ELEVATIONS ABOVE THE OCEAN
16000 FT.
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
GALERA 15666 FT
CHICLA 12215 FT.
OROYA 12179 FT.
CUZCO
F.C. CENTRAL DEL PERU
F.C. AREQUIPA A PUNO
AREQUIPA
SICUANI
LA RAYA
CRUCERA ALTA
F.C. JULIACA A CUZCO
JULIACA
PUNO
LAKE TITICACA
F.C. MOLLENDO A AREQUIPA
CALLAO
LIMA
MOLLENDO
MEJIA
30 MILES
60
90
120
150
180
210
240
270
300
330 MILES
PROFILES OF RAILWAYS IN THE PERUVIAN ANDES

PLATE I.

mit of the western range at Crucero Alta, 118 miles from Arequipa, at an altitude of 14,666 feet above sea level. With the exception of the development, which has extremely heavy work on it, as well as heavy grades, the rest of the line averaged light grades and work. The track-laying gangs on this road were Chileans, who wanted beans at every meal. Dried beans cannot be cooked in an open pot at such altitudes, so a special one was made, large enough for all, and closed, but with a safety valve attached, set to bring the pressure high up enough to heat the water over 212°.

Puno the terminus is on Lake Titicaca. A small steamer starts from there and crosses the lake to Chilalaya in Bolivia. From there the capital, La Paz, is reached by 70 miles of good stage road. Another steamer runs on the river Desaguadero, which flows from Titicaca to Lake Poopo, a distance of over 300 miles. The road to Cuzco branches off at Juliaca, 29 miles from Puno. It runs nearly due north, and crosses the summit of the eastern range at La Raya, at an elevation of 14,240 feet, and 86 miles from Juliaca. It then runs down the eastern slope 26 miles to Sicuani, the elevation of which is about 11,000 feet. When finished the lowest elevation on the Cuzco branch will be 10,050 feet above tide.

The most celebrated of all the roads is the Ferro Carril Central del Peru. It starts at the docks in Callao and keeps rising until it reaches 15,666 feet, about the height of Mont Blanc. The summit is 106.1 miles from the coast by the road and not over 75 in an air line. It then descends to Oroya, 30 miles farther, and falls 3,489 feet in that distance. Two hundred and sixty-four miles farther it will, when completed, reach the navigable waters of the Amazon. This extension will not probably cost more than half as much as the finished portion. There are few opportunities for development, as the main valley is so narrow and the side valleys few and mostly not available, so switchbacks are required. There are eight of these on the road. Four below those shown on the plan. Four are double, of which the one shown at Chicla is the largest. A line drawn across the valley there will cross the track five times. The sides of the valley are very steep and rugged, as shown by the number of tunnels that

PLATE II.—DEVELOPMENT OF THE SUMMIT SECTION OF THE F. C. CENTRAL DEL PERU.

are mostly through rock spurs. There are 57 of these, all in a distance of 24 miles. On the western side the maximum grade extends for 60 miles. The tail track of each switchback is level, or rising toward the end, and the switches are level spurs at each station. Where the switchbacks are long or are single, turntables are used, and the engine turns and goes to the other end of the train. This is the case at Chicla, where there are two turntables, the upper one being about 500 feet above the other. The slopes on the eastern side are easier and the valley wider. The maximum grade runs out in 16 miles, and only one small, double switchback is used in the 37 miles to Oroya. Work began on this road in 1870, and track was laid to Chicla in 1875. Then the Peruvian Government got into financial difficulties and stopped the work and also paying interest on the bonds.

After a number of years it made an arrangement with the bondholders by which it was to turn all the roads over to them for a term of years in part payment of the debt. They were to build the 50 miles necessary to finish the road to Oroya. This work was resumed in May, 1890, and the track was laid into Oroya on January 10, 1893. All this work was done at an altitude above 12,000 feet, the most difficult and important of it above 15,000 feet, the two largest bridges and eight of the tunnels being included in this section.

The bridges were made in England, and their erection was a matter of from four to six weeks. As time was limited on account of delay of material, it was necessary to make the false work for these bridges strong enough to carry the material-train so that the track-laying would not be stopped while the riveting was being done. The riveters did not average a week's work each. The altitude was too much for them; some few staid all the time, but only worked about half of it; many started back on the next train.

The Belgian system of working the tunnels was adopted, to reduce the expense of timbering as much as possible. The only way to get long sticks to the front was to have them carried by men. Derricks were built up from plank, but solid sticks were needed in timbering in the tunnels. The heading was run through above the springing line of the arch, and all the upper portion

taken out. Where masonry was needed, the sides were cut down enough to allow a plank 3 x 12 feet to be imbedded in mortar, so that the top was at the springing line. The arch was built on this. Then the middle was cut down to sub-grade, and the excavation carried as close to the sides as possible and still leave enough to support the arch. Alternate sections of about fifteen feet in length were then cut out to full width for the side walls, the arch being supported on posts as soon as there was room to put any in. There was space enough back of these posts to build the wall to over half its height; then the parts between the posts were closed up and wedged, quick-setting cement being used. The posts were removed one by one, and those spaces closed up in the same manner. The plank under the arch was cut out as each piece of masonry was closed up.

When one side of the arch was supported on posts, the other was not touched until the masonry had fully set. None of these tunnels had to be lined throughout.

The tunnel recognized as No. 56, or the Galera Tunnel, is the summit of the Ferro Carril Central del Peru, at the elevation named, 15,666 feet, the Galera Pass, under which it was cut, being over 17,000 feet above ocean level. The maximum grade of four per cent. continues from the western portal more than half way through the tunnel, but from the summit to the eastern portal the grade is but 1 in 500.

It was in this tunnel only that an excess of water was troublesome, and poor roofs were encountered only in this and in No. 45 tunnel. In the Galera Tunnel a break in a portion of the arch which had been built some years before, filled the entire tunnel section for a distance of 75 feet.

The removal of this, without letting any more come down, was a very slow and expensive job. The rocks were generally split by wedges, blasting only being resorted to when the top seemed secure. Small charges were used. Timber was used very liberally, and as each stone was taken out that part was secured.

Most of this timber was destroyed when the arch was rebuilt, being cut away piecemeal to make room for each stone. The cost of this was materially increased on calm days when men

had to get off the scaffold to recover their breath in fresh air. The lamps smoked very much in that high altitude.

For a few days after the track was laid, until it was surfaced up, the engines, hauling material, slipped very much on the heavy grade in this tunnel, and the trainmen were nearly suffocated in passing through it. On the eastern side, after passing the large bridge, there were no special difficulties, in grading or laying the track to Oroya.

DISCUSSION.

Mr. George S. Webster.—What load can these locomotives take up the four per cent. grades?

Mr. Maxwell.—They usually carry a train of 5 cars of ordinary size—10 ton cars—or say a net load of from 40 to 50 tons. Two passenger coaches, a baggage car and one freight car constitute a passenger train.

A Member.—Is any portion of the railroad system above the snow line?

Mr. Maxwell.—The snow line is higher than that. Some of the glaciers come down as low as the tunnel. The snow line is found there at an elevation somewhat above 17,000 feet.

Mr. John Birkinbine.—About what latitude is that?

Mr. Maxwell.—I think about 11 degrees south.

Capt. D. B. Dahlgren.—Are the men troubled with Verugas?

Mr. Maxwell.—At elevations from 2,000 to 8,000 feet much trouble is experienced on that score. At the Verugas viaduct it was difficult to keep workmen on account of the mortality from the disease. I never heard of Verugas above an altitude of 10,000 feet.

Capt. Dahlgren.—Will you please explain to the gentlemen what the Verugas is?

Mr. Maxwell.—I can describe its appearance, but our doctors said that they did not know the cause of it. The men are first attacked in a way similar to a severe case of mountain fever. If they recover from that, an eruption breaks out over various parts of the body, especially on the hands, nose, points of the ears, and eyebrows, presenting a very peculiar appearance. With

proper care they get well in time. If the patient takes cold, however, the eruption is driven in and death follows invariably. The eruptions are wartlike in appearance and bleed freely. I am unable to state the exact cause of this disease. The general impression seemed to be that it was due to the water, although I have known men to die of the Verugas who were never known to use water internally. I have seen animals with the Verugas warts on them.

Mr. Webster.—Was the proposition of adopting the rack system ever considered?

Mr. Maxwell.—No, sir; the conditions were not favorable for its use. The grade of the main road was too broken—first light, then heavy. I doubt very much if the Junta Central engineers would have cared to consider anything of that kind.

Mr. Birkinbine.—It strikes me that an interesting point which Mr. Maxwell could enlighten us upon would be an answer to the question, "Where are you going to get the traffic to support these roads?" What is their real object? Is it merely to climb mountains, or is there a good deal of material to be moved up and down for the support of the population? In other words, "Where is the money to come from to cover the large cost of that construction?"

Mr. Maxwell.—They were built by the Government to develop the country. There is quite a population on the eastern slope, and Lima now gets her supplies from there.

Mr. Birkinbine.—They have to use foreign coal?

Mr. Maxwell.—They do now; but there is coal on the eastern slope.

Mr. Birkinbine.—Is there any possibility of their connection with the Chili and Argentine Railroad, which is nearing completion further south?

Mr. Maxwell.—A connection might be made north and south by making use of the principal streams.

Mr. Max Livingston.—What kind of fuel is used on these roads?

Mr. Maxwell.—Coal brought over from England. The Southern system uses coal altogether.

Mr. Livingston.—Would not petroleum be considerably

cheaper? One or two of the roads further south are using this quite successfully.

Mr. Maxwell.—There are oil wells along the coast. After the illuminating oil was extracted the residuum was brought in tank-steamers to Callao, transferred there in bulk, and then used as fuel on the road. Its cost was about half that of coal, but I have learned that they have since got into difficulty with the owners of the oil wells, and have been compelled to again resort to coal.

A Member.—Had you any difficulty in procuring laborers to work at such high altitudes?

Mr. Maxwell.—We employed Indians mostly, paying them from 80 cents to $1.00 in silver money, worth about half what ours is now, or 40 to 50 cents. These Indians came from long distances when they learned that they could get good pay for their work. They would usually work about a month at a time, and then leave until their earnings had been spent.

Mr. James Christie.—In what portion of Peru are the nitre beds found?

Mr. Maxwell.—The nitre beds are situated in a territory which belongs now to Chili, and which belonged formerly to Bolivia. Some Chilians went there to prospect for metal. They established some good silver mines, and afterwards found these deposits of nitre. I think they are located 60 to 100 miles from the coast. They belonged at no time to Peruvian territory.

Prof. Walter L. Webb.—Do foreigners experience any trouble from the climate of Peru, or do they become acclimated easily?

Mr. Maxwell.—The climate is generally healthful, except in those parts where the Verugas prevails. At an elevation of 8,000 to 10,000 feet it is delightful, also on the coast, where barren of vegetation. Where vegetation exists, fever is also found. It is one of the most even climates in the world. I had thermometric observations made every four hours for one year, and found an extreme variation of only 21 degrees, the daily variation being but 10 degrees, and the maximum range during the whole period from 59 to 80 degrees. That was directly on the coast.

Mr. Birkinbine.—Do you have fogs there?

Mr. Maxwell.—Fogs prevail during the rainy season. It was

sometimes a little cold when the wind blew from the ocean during the afternoon and night.

A Member.—Are the mountains pretty well timbered?

Mr. Maxwell.—On the contrary, no timber is found there. I may add that in ascending those high altitudes, some people cannot proceed beyond an elevation of 5,000 feet, but usually sickness does not occur below 12,000 feet. It usually comes on very suddenly like seasickness. The only remedy is to descend to a lower elevation, otherwise death is likely to ensue from congestion of the brain or the lungs. The action of the heart also becomes much affected at these high altitudes.

X.

WRECK OF THE CONNERSVILLE (IND.) BRIDGE AND ITS TEMPORARY REPAIR.

By Joseph Kemper, Active Member of the Club.

Read May 18, 1895.

On the Cincinnati, Hamilton and Dayton Railroad, about a half mile below Connersville, Ind., there is a bridge which crosses the White Water River in a southeasterly direction. This bridge was of three spans of 165 feet each, center to center, and was, at the time of which I write, composed of wood and iron combination through trusses, single track, Warren pattern with vertical posts and hangers, or suspension rods.

The upper chord was of wood, tin covered, as was also the upper system of sway bracing, with, of course, the exception of the rods. The width of the bridge was about 16 feet and depth about 30 feet.

About two o'clock in the morning of July 15, 1892, while an east-bound freight train was standing on the bridge, a "wild" or runaway freight train came rushing down the one per cent. grade from Connersville and crashed into the rear of the train on the bridge, resulting in the collapse of the two end spans of the three which composed the bridge. The middle span was left standing, practically uninjured, with four freight cars on it. The "wild" engine struck the train quite near the northwest end of the bridge and after the crash was left a wreck on the embankment, the most battered specimen of the locomotive builder's work I have ever seen. The engineer and fireman of the engine jumped before the crash and escaped serious injury. Two brakemen of the train that was struck went down with the wreck, and were seriously hurt. The loss was between $10,000 and $20,000 on the bridge; the loss from other sources I could not learn.

From the appearance of the broken northwest truss, it seemed that the train at that point must have "buckled," the truss falling apparently more in a sidewise than in a vertical direction.

This was less marked in the broken southeast truss. The channel of the White Water River at this point was narrow, the entire flow of the river being under the southeast truss, and of no great depth, probably not exceeding 8 feet at its maximum. The rest of the river bottom was at that season of the year (midsummer) quite dry, and being of a gravelly nature made the work of clearing and construction much less difficult than would have been the case earlier in the year.

Immediately upon receipt of the news of the wreck, the wires were busy in all directions and daylight found construction gangs, wrecking and pile-driving crews, on their way to Connersville. Lumber of all necessary kinds was taken from yards and from work under construction near and far; in fact, all roads led to Connersville. A frame dining room and kitchen were erected, which were affectionately dubbed "the grub sheds." The food was excellent in quality and plentifully provided. As a mark of distinguished consideration, the officers and engineers were supplied with napkins. Connection was also made for electric light service. A telegraph office about as big as a packing box was built convenient to the bridge. Mr. Charles Neilson, now Second Assistant Postmaster General, who was then General Superintendent of the C. H. & D. R. R., was on the scene, as was Mr. Charles Wood, Chief Engineer, under whose direction the earlier work was done. The importance of having a person high in authority on the scene of an accident was evident in this case. Whatever was necessary, could be at once obtained through the General Superintendent, and his authority covered everything. It is such an emergency as this which puts a great railroad company to the test. We grow accustomed to thinking of a railroad as a thing of method and system, but anything extraordinary shows that it possesses in a high degree those qualities we so much admire in a man—energy, intelligence, and a store of reserve force. Every officer seemed bent upon doing his very best work to resume traffic. I saw one of the officers (Capt. Hill, Superintendent of Bridges,) impatiently watch a man wielding a sledge and finally he said, "Let me have that," and he certainly did the better work of the two. The great loss resulting from delayed and diverted business always acts as an incentive to heroic effort

in the highest quarters, and the example is contagious. No expense is spared, and whatever is necessary is obtained and that quickly.

Our party of engineers was then on preliminary and location work in the woods of the soft-coal country in southeastern Ohio, but as soon as possible we received word calling for all hands with both instruments, and we left the hills and woods of Jackson County behind us, for the more exciting field of work. On our arrival, we found that a temporary trestle bridge had been constructed, which for excellence and quickness of work was considered remarkable. The river being low, and there being no probability of an early rise, it was decided to curve from the main track to the eastward, descend a steep grade to the dry river bottom, across the bottom to the northwest and near the abutment, connect with an old gravel track which ran to the gravel pit to the east, climbing the steep grade of the gravel track, connection was once more made with the main track. So, after the descent of the first grade mentioned, the greater part of the trestling was of very shallow depth; at its lowest point, the stringers resting only on well-bedded mudsills. The trestle bents were composed of 12″ by 12″ plumb-posts, batter-posts, sills and caps, with 8″ by 16″ mudsills laid flat. The bents were braced longitudinally with 2″ by 12″ pieces, the same size being used for sway bracing where depth of bent made it necessary. The stringers were composed each of two 8″ by 16″ pieces, with 2″ by 12″ by 3′ by 3′ packing blocks. The bents were spaced 15 feet apart, center to center. This trestling was erected within twenty-four hours after the wreck had occurred, and was done without the aid of the instruments, the curve being an excellent specimen of a track foreman's skill in "lining up." This work was intended to be used only until the bridge could be replaced on its old line.

As soon as the trestle was completed, the work of clearing the wreckage away from between the bridge piers was begun, the work on the trestle not having been hindered by it, as that work was to one side of the bridge. The Detroit Bridge Company was then building a bridge at Liberty, Ind., about fifteen miles south of Connersville, and a gang of bridge men came

to the wreck to assist in taking apart the broken trusses. With sledge-hammers the pins were driven out of the connections, enabling the various members to be drawn to one side. For this purpose a "dead man," as it is called, was planted about 75 feet to the west of the bridge, to which block and tackle were rigged, while an engine on the embankment above furnished the power. As soon as the eye-bars, floor-beams, etc., were disconnected, they were drawn to one side, making room for the trestling, which was to be put up on the gravel bottom there at the Connersville end of the bridge. These trestles were similar in construction to those of the temporary trestle and were spaced 15 feet apart, center to center. The wrecked cars at this end had contained a cargo of miscellaneous freight. One car had contained, among other things, two dozen hams, which in some way mysteriously disappeared. Another car had a cargo of fresh hides, which did not disappear, but in the extremely hot weather at that time were very much in evidence. The cars which remained on the uninjured span were with one exception in pretty good shape—a few broken couplers and damaged ends, otherwise, with little repair, they were ready to be moved when the bridge was finished.

At the southeast end the process of clearing was similar to the other end, except that here the pile-driver did great work in lifting and moving heavy objects out of the way. The distance from the base of rail to the dry river bottom was about 20 feet and about 22 feet to the water level.

As soon as the channel was cleared, the pile work was gotten under way, the pile bents being composed of four piles each, about three feet apart, center to center. Distance between bents was about 22 feet, except near the pier where one trestle bent was used, which rested upon the ends of the old piles used as falsework, when the broken truss had first been built. These old piles were surrounded by rip-rap, and were in an excellent state of preservation near the water line. Their tops were sawed off to a level and the bent rested upon them. While we were giving points of "cut-off" for the piles, we had occasion to leave the leveling instrument to do some measuring, and left the instrument in care of a tall, rawboned section hand. When we re-

turned shortly afterwards, we were amazed to find him with his arms folded across the instrument, leaning upon it in a very comfortable way. He was told very emphatically that his method of taking care of an instrument was not regarded with very high favor in engineering circles.

After the trestling of the northwest span was finished and the tracks laid, the cars which had remained on the uninjured truss were drawn off to the siding in the direction of Connersville. There then remained only the southeast span, the pile work of which was finished. We had given the centers for the track on the caps of the bents, the stringers had been laid and the trackmen were hammering away in the growing darkness. It had been a very hot day, and the sunset was, in keeping with the day's temperature, very fiery. The "Well's" lights were soon lighted and about half-past eight the bridge was ready. It had been a period of pretty hard work, night and day, and as we gathered around the telegrapher's box, with our instruments, waiting for the Cincinnati express, in the dim light of the telegrapher's lamp, we looked what we certainly were—a very tired body of men.

The time occupied in the entire work, including the temporary trestle, clearing of the wreckage, and the work of replacement on the old line of the bridge, was about five days.

XI.

CERTAIN INTERESTING FEATURES IN THE MANUAL INTERLOCKING OF RAILROADS.

By George H. Paine.

It has been suggested that there are enough interesting features connected with the art of interlocking railroad switches and signals to make a palatable talk for the members of this Club. This I am quite sure of, but whether I shall be able to bring out these features in an interesting manner I have my doubts.

In the early days of railroads, with their light, slow trains, the operating question could have been scarcely, if at all, more serious than is nowadays that of the nearly obsolete horse-car line, but the railroads grew rapidly, switches multiplied, travel increased, and the necessity for improved methods gave birth to interlocking.

The first step in this evolution was undoubtedly brought about by an effort to reduce the cost of handling trains. As the train service became heavier it was found advisable to station men permanently at certain switches so that they might be operated without having to stop each train which found a switch wrong at such places as junctions, entrances to yards, etc. From this one fact all interlocking probably took its rise, for it was soon discovered that one man could take care of a great many switches if he could only get to them, so somebody proposed taking the switches to the man, which was done forthwith.

In the meantime someone else suggested that if an engineman could, through a signal, know something about how he was going to find a switch a little before he reached it, time and money would be saved, since he would not then be always required to come nearly to a stop when approaching switches in obscure locations or else run the chance of a disaster.

It was self-evident at this point that the man who controlled the switches must also control the signals: in this way the operating mechanism of both signals and switches came to be placed side by side. But even yet there was no interlocking and

it probably required a very nasty wreck, a "crowner's quest," a storm of letters to the papers and some costly lawsuits to bring about that happy and fortunate combination. It would be useless to give you individual names and dates, but in recounting the growth of interlocking one should never omit to say, that to our conservative and often (as a race) slow-moving English cousins we owe this humane idea. It must also be recorded to our shame that the use of interlocking had reached a highly developed state in England before even a start had been made in this country. Why this was and still is, so far as it concerns many of our important railroads, is probably to be accounted for by our notorious disregard for the value of human life, which is otherwise illustrated by the inert way in which lynchings, riotous strikes and other social disorders of the kind are treated by our National and State Governments and for that matter by the public at large. Nevertheless, in interlocking, an advance is to be noted in certain localities, which so far has taken the form of mandatory laws, not very strictly enforced, governing the operation of grade crossings.

Railroad Commissions are being created in the different States, and where they already exist are being invested with increased powers of administration.

These facts taken in connection with a more enlightened view on the part of railroad officers, the greater attention which is being paid to the subject by the technical journals and the public press, all argue that we are moving toward a point where the management of railroads will be conducted with greater safety to life and property than has been the rule in the past.

The aim of interlocking is to first decrease the dangers due to the movement of trains; second, to facilitate, and therefore reduce, the cost of handling trains. Fortunately the two usually go hand in hand, for in the management of trains that plan which will result in an ultimate economy is likely to prove the safest.

To the friends of signaling the most discouraging feature of its introduction to this country was the mental inertia displayed by many of the persons who should naturally have been anxious to see it brought into practice: to be met with the statement, as

has happened many times to me, "I have been a railroad man for forty years, and I never saw the need of any signals," or words to that effect, was simply maddening. But these are old sores, now nearly healed, and not many persons can be found at present who would have the courage to admit such a belief.

Besides the devices which I shall mention are many more, perhaps their equal in interest and ingenuity, but it would take too long to describe them adequately, and a loose description would be of no value.

The theory of all interlocking is perfectly simple, the practice is most complicated especially when there is a large number of levers in a machine. Not only may a certain arrangement of tracks and signals be interlocked in several different ways, according to the taste of the purchaser, but a certain scheme having been decided upon, the several combinations which result can be secured by widely different arrangements of locks. Since except in the smallest plants, no two schemes are ever seen which are exactly alike, an interlocking formula would be of no value if one could be arrived at.

The locking on machines is performed by the shifting of what are called dogs: the series of dogs which are connected with one lever being moved in such a way as to either prevent or permit the movement of all the other levers concerned in that combination. The dogs are mounted on locking bars, which in turn are fastened, through the medium of a small shaft and a link, to the latch of the lever. By this arrangement all of the necessary levers are locked fast before any movement takes place in the lever to be thrown and none of those levers which have been locked, but are to be unlocked, are released until the lever in action has reached its new position and is latched there. Furthermore, no change in the locking takes place during the movement of the lever itself. The technical expression for this essential feature of all good locking is "preliminary."

In order to make this clearer I have shown the principal elements on Plate I, but it is to be noted here that this is only one arrangement of many, although it is that which is most used in this country:

Fig. 1 shows the connection between a lever and its interlock-

FIG. 1.

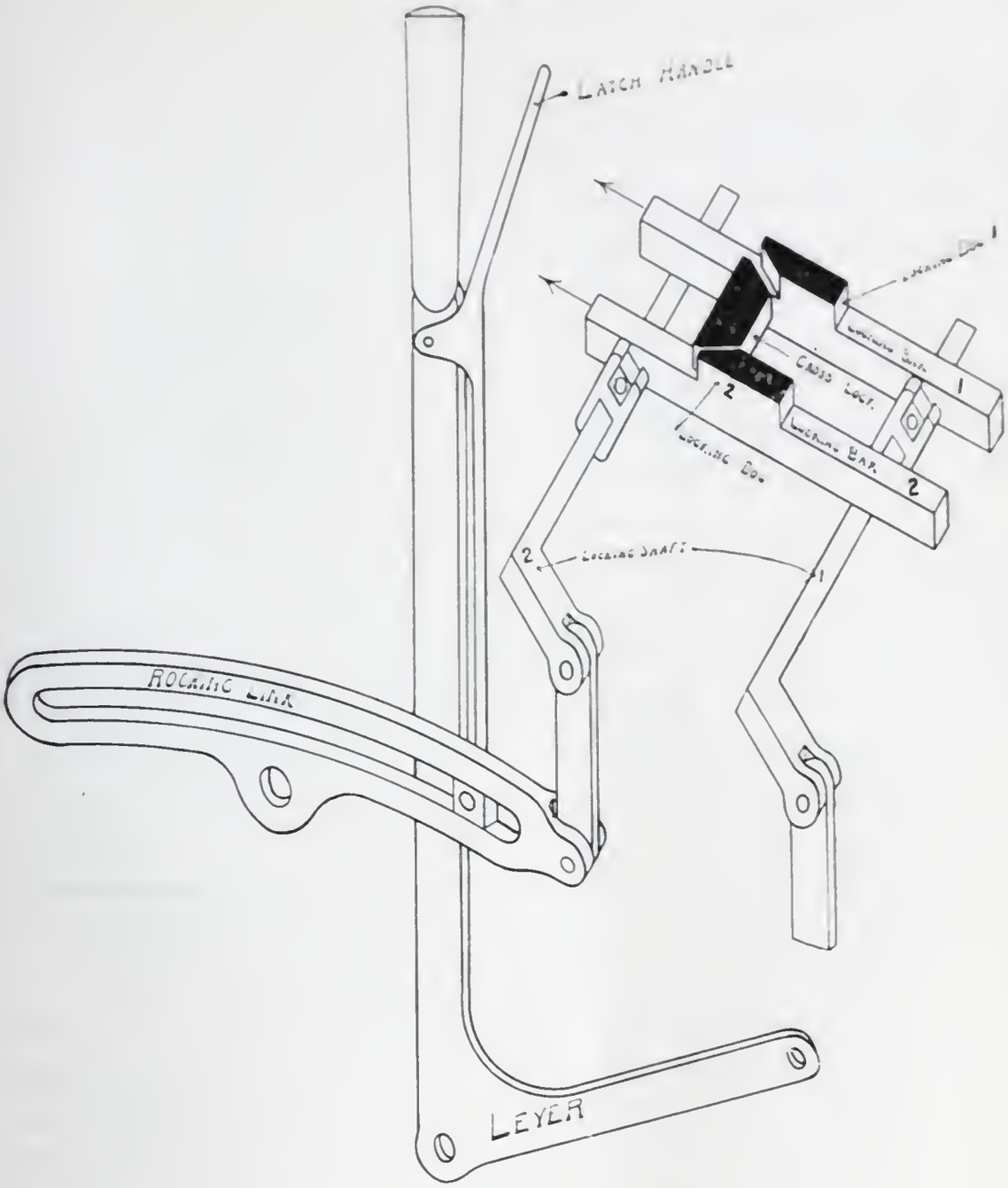


FIG. 2.

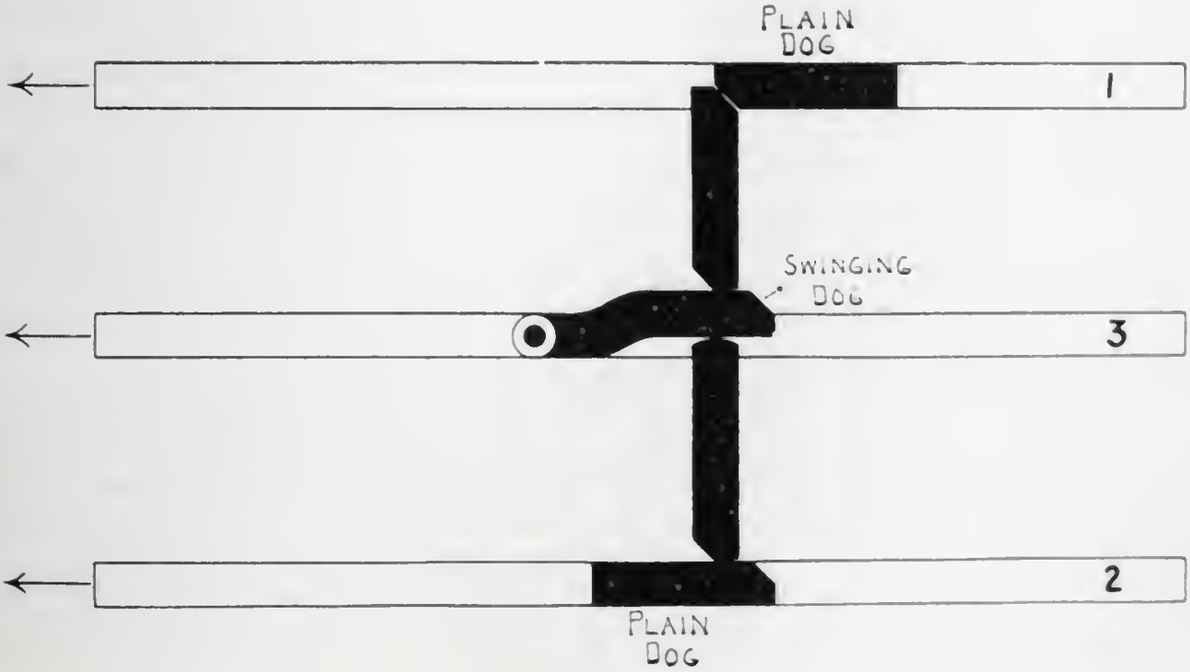


PLATE I.

ing parts; the latch is joined with the rocking link by a block which is free to move back and forth in the slot of the link when the latch is raised; as shown, however, the latch and link are lowered and the lever occupies its normal or forward position. Upon raising the latch, the link performs half its motion and its slot assumes a position of which the axis of the lever is the center. This act drives the locking-bar corresponding with that lever by means of the locking shaft; the connection between the shaft and bar consists of a block that closely resembles the one attached to the bottom of the latch-rod. The reversing of the lever now takes place, following which is the lowering of the latch-rod into its new catch and the completion of all the functions of that lever and its locking. No matter whether the lever is normal or reversed when the operation of moving it takes place, the first thing to happen is the raising of the latch which accomplishes all of the locking, then occurs the movement of the lever, during which no change in the locking takes place, last the lowering of the latch-rod which releases those levers that are to be moved next. Fig. 1 shows but one lever, but it is to be understood that a lever is also connected with locking shaft 1.

It is evident from Fig. 1 that any movement of the locking bar 2 will drive the cross-lock against the dog 1, on locking-bar 1, and will continue to hold lever 1 locked so long as the locking-bar 2 retains that position. This is one of the simplest locks to be found on a machine, and together with two others is the most used. The real complications of locking are met with in the special locks which always concern three or more levers; for instance, lever 1 locks lever 2 reversed when lever 3 is normal, or again, the word lever being omitted but understood, 12 locks 46 normal, 49 reversed and 65 normal when 17 is reversed, 20 reversed, 22 reversed, 24 normal, 31 reversed, 33 reversed and 35 normal.

An invariable accompaniment of a special lock is the swinging dog shown on Plate I, Fig. 2. This swinging dog is mounted on a trunnion at one end, but where it is touched by the cross-locks at the other end it is free to move. The combination shown in large scale on Fig. 2 is the manner of constructing the first special lock recited above, 1 locks 2 reversed when 3 is normal.

If in this combination the locking-bar 2 is first moved to the left, it will be possible to move locking-bar 1 to the left, swinging the dog on locking-bar 3 at the same time through the cross-locks; this results in locking lever 2 in its reversed position when lever 3 is in its normal position by the unlatching of lever 1, which is the object sought.

This lock may also be read, 1 locks 3 reversed when 2 is normal, and depending on the number of elements in a lock it may be read in several different ways, which at first sight seem to bear no relation to each other.

When taken in connection with the fact that special locks may often be built in more ways than there are levers in a combination and that each of these methods has many readings, some of which coincide with the readings of other methods and some do not, the condition of a young man's mind who begins to seriously study the subject may be more easily imagined than described.

One and only one comfort exists: a lock which is right according to one reading or construction, is so far as I can discover, right in every other manner of reading or constructing it.

Since the effects of a special lock are often quite remote, the ability to foresee them constitutes to a large degree the skillful signal engineer, while the failure to do so will result in a number of duplicate locks; these, although they do no positive harm are burdensome and of course add to the cost of the work. As the locking on a machine cannot be solved by any mathematical process, the accuracy of the work must be determined by testing the levers in every possible combination. This should be done at least three times by as many competent persons: once before the machine leaves the erecting shop, again by the foreman who places it in the cabin, and lastly by the person who accepts the machine on the part of the railroad company. These three tests, if they are conscientiously made will pretty certainly develop any faults of commission or omission.

Next to the machine itself the most interesting features of interlocking are the signals, the selectors, the facing-point locks, the detector bars and the compensators.

The object sought in these arrangements is to make it abso-

lutely certain that the proper signal shall be cleared, that every switch over which a train must pass is set and locked in the correct position and that every signal which controls a conflicting movement will be locked in the danger position.

Signals are divided into two general classes, "home" signals and "distant" signals: the home signals are subdivided into "main line" and "dwarf." The usual rule now is to place not more than two arms on a main line home signal, as shown by the figure on the left of Plate II, the upper one controlling the fast or important route and the lower one all other routes; of course when there is no switch facing a main line home signal only one arm is used. An exception is made to this rule at a junction when there are three or more routes. Here three arms would be necessary; one, the top one for the through main track, the next for the branch main track, and the third for the remaining route or routes. With dwarf signals (the small lower figure) the common practice is to use only one arm which controls the movement over all routes.

Main line home signals are never used except to control trains which are moving in the direction of the traffic on main tracks; on single track, therefore, a main line home would be used for movements in both directions. Dwarf signals on the contrary are used only on side tracks or against the traffic on main tracks, in both of which cases the movement is presumably slow.

The distant signal (shown in its two positions on the right) is really nothing but the echo of a main line home signal; it can, strictly speaking, have no separate existence since it only announces to the engineman the probable position of the home signal to which it relates. I say probable position because the distant signal may be in the caution position without regard to the position of its home signal, but it cannot be cleared until after the home signal has been cleared. The distant signal is open to one serious objection as at present used; although it tells the truth when the engineman passes it in the clear position, there is usually nothing to prevent the signalman from inadvertently changing all of the combinations after the engine passes the distant signal and before it reaches the home signal. This has often resulted disastrously and can only be prevented by placing an electric

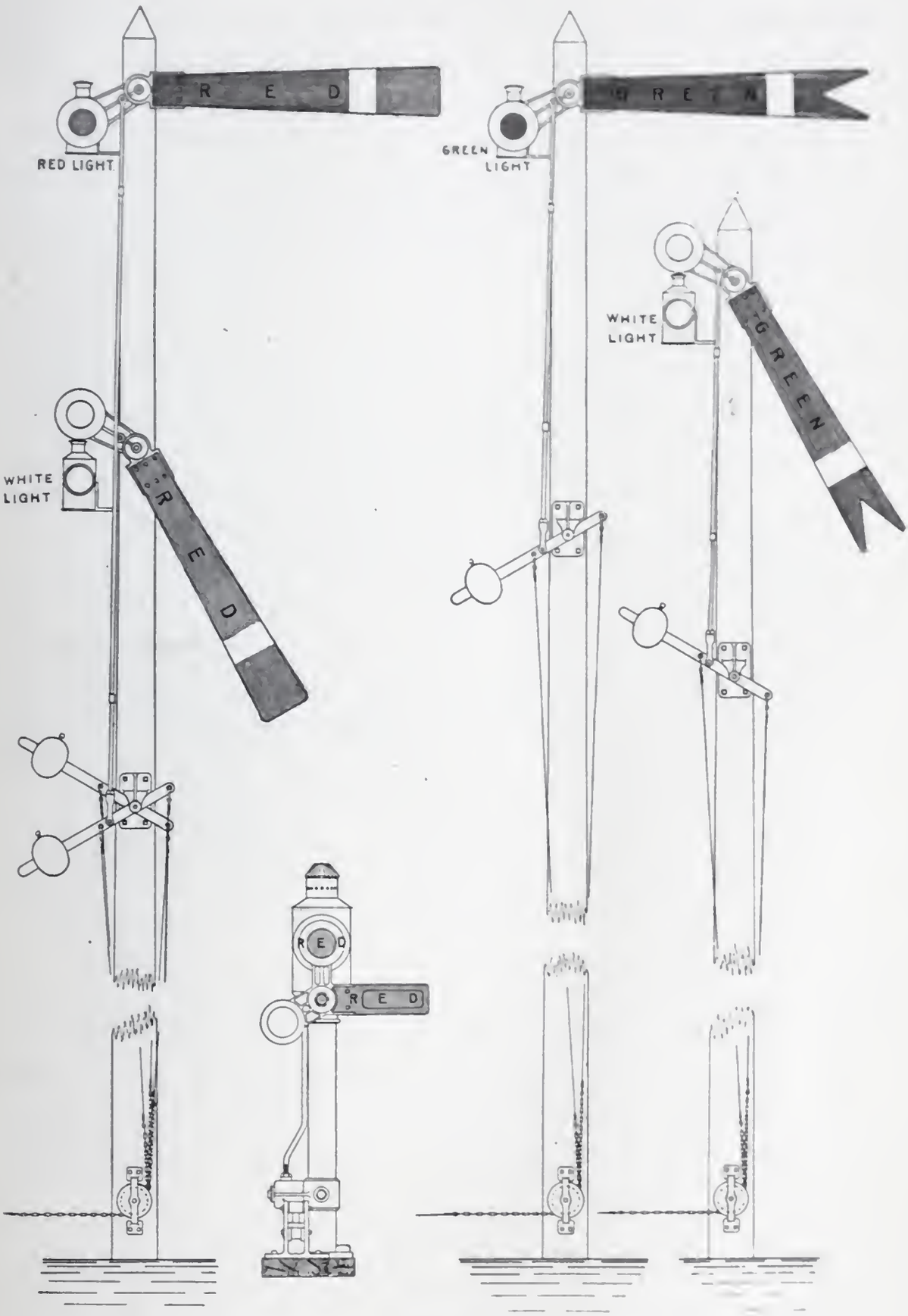

R E D
RED LIGHT
WHITE LIGHT
R E D
GREEN LIGHT
WHITE LIGHT
GREEN
RED
RED

PLATE II.

lock on either the home or distant signal lever which will automatically lock the route as soon as the train has passed the distant signal, if the distant signal has previously been cleared. When the conditions are understood it is evident that the electric lock should be engaged only when the distant signal is in its clear position. This arrangement is extensively used on the interlocking plants in New England, and it is to be regretted that a wider application of it is not insisted upon in other parts of the country.

Since the distant signal is only intended as a warning, in order that it shall perform its duties successfully it must be placed at such a distance from its home signal that any train which is cautioned on passing it shall be able to stop before reaching the home signal. It is safe to say that there are many distant signals which do not meet this condition, since they are placed at points not often more than 1,200 feet from their home signals. This would not be sufficient if all freight trains were equipped with air-brakes, but I think I need hardly tell you that it is a far cry to the time when we shall see that accomplished, and the railroads, therefore, following the present plan, are doing a thing which is known to be wrong, and which should be plainly evident. There is an immediate necessity that distant signals shall be placed not less than 1,500 feet, and possibly more, from their home signals on level track, increasing the space if there is a falling grade, and if there is a rising grade, proportionately reducing it.

Home signals should be placed preferably at the fixed distance of 50 feet from the nearest facing-point switch that they govern, and not more than 300 feet from the farthest facing-point switch. Under certain conditions the distance between the home signal and the nearest facing-point switch is reduced to 5 feet, but it is not a desirable arrangement if it can be avoided. At trailing switches the home signal should be placed from 10 feet to 300 feet back of the clearance point. It must be understood as a law that signals must never overlap what is considered the danger point.

Except, I believe, on two railroads in this country, signal arms always point to the right when viewed from approaching trains

which they govern, and signal posts are usually placed on the right hand side of tracks which they govern. The last rule, however, is not an invariable one.

Distant signal arms are usually painted green and always have a fishtail end.

Home signal arms are usually painted red and, except on one railroad, always have a square end. The red and green just mentioned are, however, only displayed on the side of the arms from which trains which they govern approach; the reverse of all arms is usually painted white.

The caution position for the distant signal and the danger position for the home signal is at horizontal line. The usual clear position for both signals is at an inclination varying from 60° to 75° with the horizontal.

A notable exception to the painting and position of the blades just stated is the plan adopted by the Pennsylvania lines west of Pittsburg, for which I believe we may thank Mr. Grafton, Signal Engineer of those lines.

All signal arms of the Pennsylvania Company are painted yellow (a neutral color), with black bands to emphasize them, and the positions of the signals are respectively, horizontal and vertical, for danger and clear, as may be seen on Plate III.

Without going too deeply into the question, it may be said that this plan offers many advantages; the extreme movement given to the arm removes to a large extent the likelihood of indefinite signals which are so common under the ordinary practice and are caused by the slack in long lines of uncompensated wire; this slack must, of course, be taken up by the lever before the signal will begin to move, and as a result, instead of moving through an arc of 60° or a little more, it is pulled down only one-half that angle or even less. There should be nothing uncertain as to the meaning of a signal when viewed by an engineman An immediate and positive impression should be conveyed to his mind, since on a fast moving passenger train there is no time for thought after a signal comes into view, and the conditions are such as to forbid the engineman from using his judgment except in very rare instances. The rule, "When in doubt take the safest course," would in this case mean stop, and at first sight

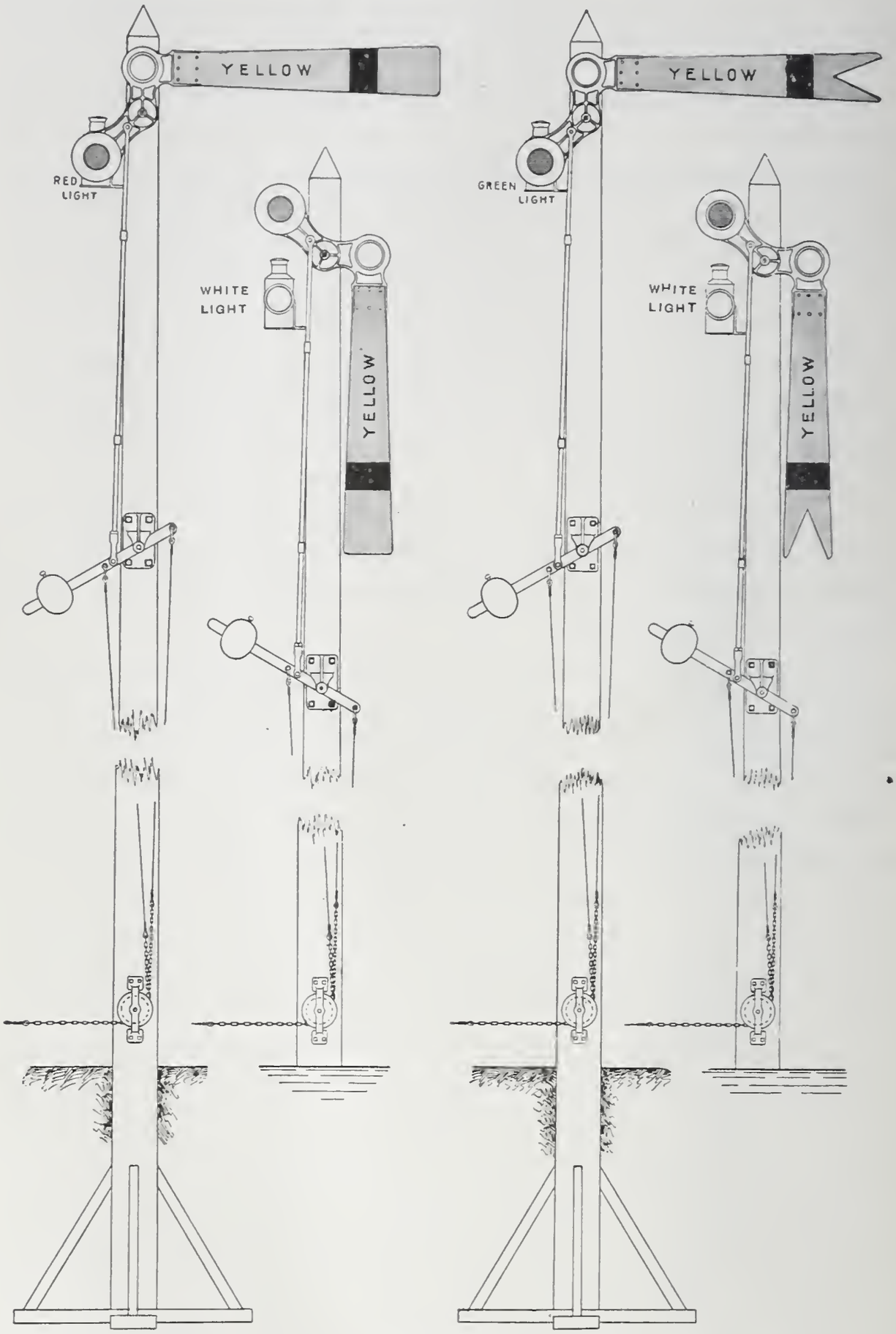

YELLOW
RED LIGHT
WHITE LIGHT
YELLOW
YELLOW
GREEN LIGHT
WHITE LIGHT
YELLOW

PLATE III.

seems to cover every possible contingency; but this is one of the rules which is most easily abused and may lead to trouble if too much dependence is placed upon it in signaling.

The other radical change in Mr. Grafton's system is the painting of the face of the arms, which, although not so important from an operating standpoint, except as it makes the blades more prominent, is perfectly consistent and is based on the correct principle that a position signal should not be dependent in any way upon color except for the purpose of distinguishing it from surrounding objects.

One point which we have failed to appreciate the importance of in this country is that very one of lending prominence to our signals. The posts and arms are painted when they are first put in service and then in many instances not touched with a brush for years, so that to an unpracticed eye they are hardly to be separated from the background. A signal post should be the most prominent object in any landscape which it occupies, and in order to secure this result it must be painted often in colors which contrast with each other in a violent manner and are not likely to be confused with anything against which they may be seen.

The lighting of signals at night is variously practiced, and I shall describe two systems, the commonest and the best, or rather what seems to me the best, yet devised.

Unless otherwise stated it is always assumed, as on Plate II, that a distant signal will show a green light for caution and a white light for safety; home signals will show a red light for danger and a white light for safety. There are three objections to this plan: first, the breaking of a red or green glass in the semaphore-casting (not a remote possibility when we know that boys will be boys) will result in a white instead of a colored light should the arm stand in a horizontal position; the possibility of an accident in this case is evident. Second, there is great danger that a foreign white light will be taken for a semaphore light, and be wrongly interpreted as a clear signal. Third, there is no indication when the arm is cleared as to whether the signal is a home or a distant, since they each show a white light when in the safety position; this information should be given on general principles.

Mr. E. C. Carter, Principal Assistant Engineer of the Chicago and Northwestern Railway, has overcome these difficulties in a most beautiful and simple manner, as will be seen on Plate IV. Here there is no white signal; therefore if one of the glasses is broken something is evidently wrong, and in fact the enginemen, where this system is used, are instructed to the effect that a white light on a semaphore-post is to be regarded as a danger signal.

Neither is there any probability that a foreign light of any kind will be mistaken for one of those signals. The last objection noted with regard to the common practice of lighting is also well covered, since it is apparent that of the four indications given no two are alike. Mr. Carter uses an ordinary lamp on the home signal, as only one light at a time is shown; but on the distant signal post a peculiar lamp is used; it has the ordinary lens back of the semaphore glass, but outside of this a wing projects, which carries a reflector.

I must state here that the clear indication for a distant signal which I have illustrated, is not the one strictly belonging to the Carter system. Usually the lower opening in the distant signal casting is covered by a shield and cuts out the light from the opening in the lamp next to the post, when the signal is lowered. This arrangement, however, I do not like so well as the one which I have embodied in the main description, since with it there is no distinction between the home and distant signals when they are in the clear position.

On Plate V is illustrated a scheme for lighting and painting semaphore blades, which is a combination of the Grafton colors and position with the Carter lights. The posts present here a rather bizarre appearance, but this is not objectionable in practice and will serve to attract attention the moment that the eyes of an engineman rest upon them. By this plan I believe that most of the objections to our ordinary practice are overcome. The blades are painted yellow, a color which has no significance in signaling rules, but which is plainly visible at a long distance; the triple black bands on the home and distant signals make them more prominent, while the shape of the bands on the blades and posts will identify them at a considerable distance. The advantage of the vertical position for a clear signal has already been gone into

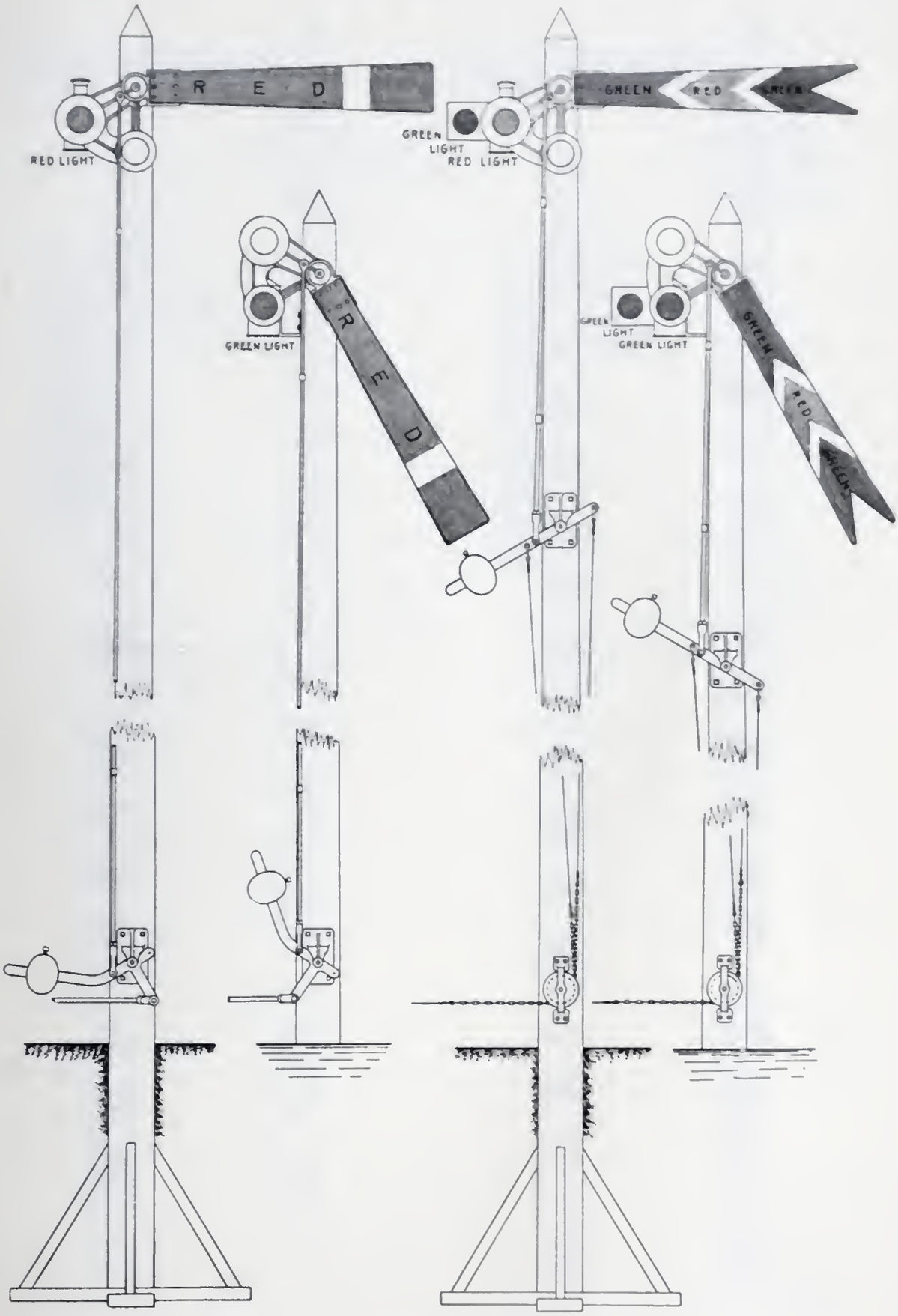

R E D
RED LIGHT
GREEN
RED
GREEN
GREEN LIGHT
RED LIGHT
GREEN LIGHT
R E D
GREEN LIGHT
GREEN LIGHT
GREEN
RED
GREEN

PLATE IV.

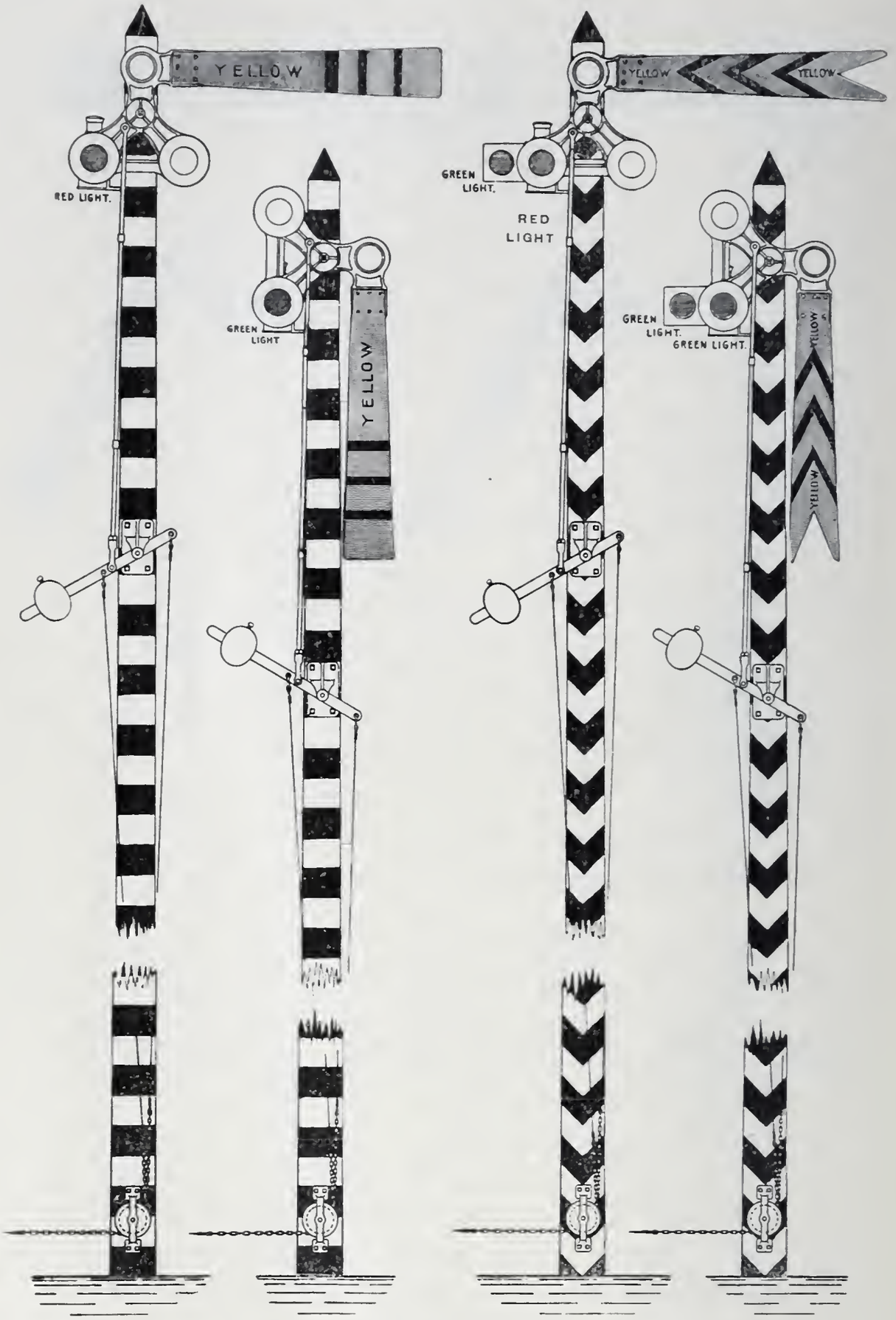

YELLOW
RED LIGHT.
GREEN LIGHT
YELLOW
YELLOW
YELLOW
GREEN LIGHT.
RED LIGHT
GREEN LIGHT.
GREEN LIGHT.
YELLOW
YELLOW

PLATE V.

and need not be repeated now, neither is it necessary to insist any further on the superiority of the Carter system of lighting.

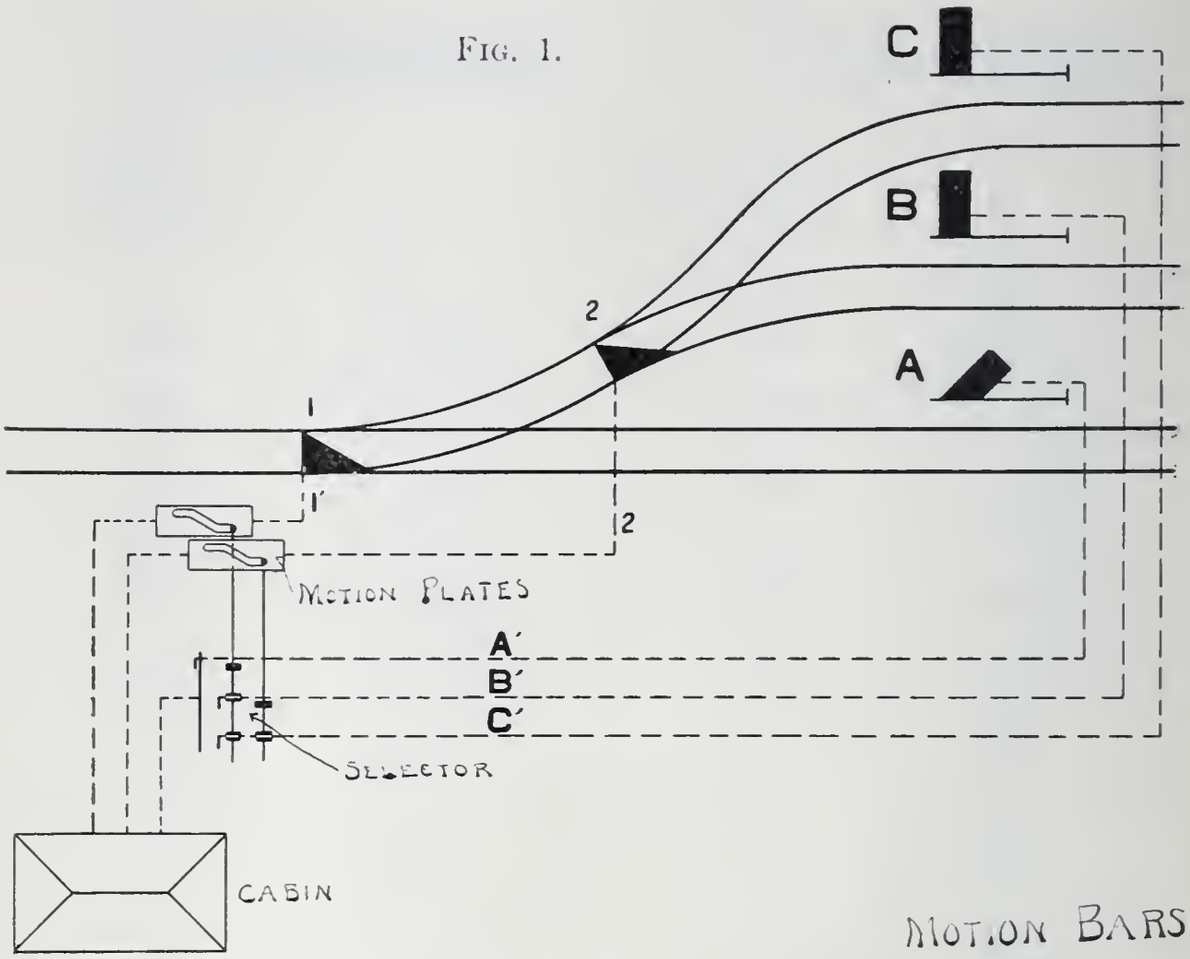
When two or more signals which control trains moving in the same direction are so related as to make it improper that more than one of them shall stand in the clear position at the same time, all of these signals may theoretically be operated by one lever through the medium of a *selector*.

The selector accomplishes two things: it provides a much cheaper plan for connecting the signals than if each signal were furnished with a separate lever, and by reducing the number of levers in a machine it simplifies its operation, which, in one of large size, is a matter of considerable moment. In practice the selector is not built to control more than eight or nine signals, although there are none but mechanical reasons against making it of any size. Except in rare instances it is placed in front of or inside the cabin which contains the machine, while near to and parallel with it are placed the pipes that operate the switches by which the selector is controlled. On Plate VI is shown what is called a two-way selector—two-way because there are two switches which control its action. This method of nomenclature, although apparently not the most consistent, is necessary since the selector, if built large enough to accommodate the switches, will always be large enough to hold the signal rods, but if confined to the size necessary for the signal rods it would often be found too small for the number of switches which must be connected with it.

On Plate VI, Fig. 1, two switches, 1 and 2, are governed by signals *A*, *B*, and *C*, while the pipes which control the switches are numbered 1′, 2,′ and the wires which control the signals are marked *A*′, *B*′, *C*′.

The switch levers in the cabin are normal, while the signal lever is reversed, as is shown by the position of signal *A* and the slide plate in Fig. 2. Inserted in the lines 1′, 2′ are two motion plates, which, when moved back and forth, cause the motion bars to slide under the hook bars. Upon the motion bars (see Fig. 2) are mounted dogs which in one position of the switch raise a hook bar from, and in the other position of the switch lower a hook bar into connection with the slide plate which is operated

Fig. 1.



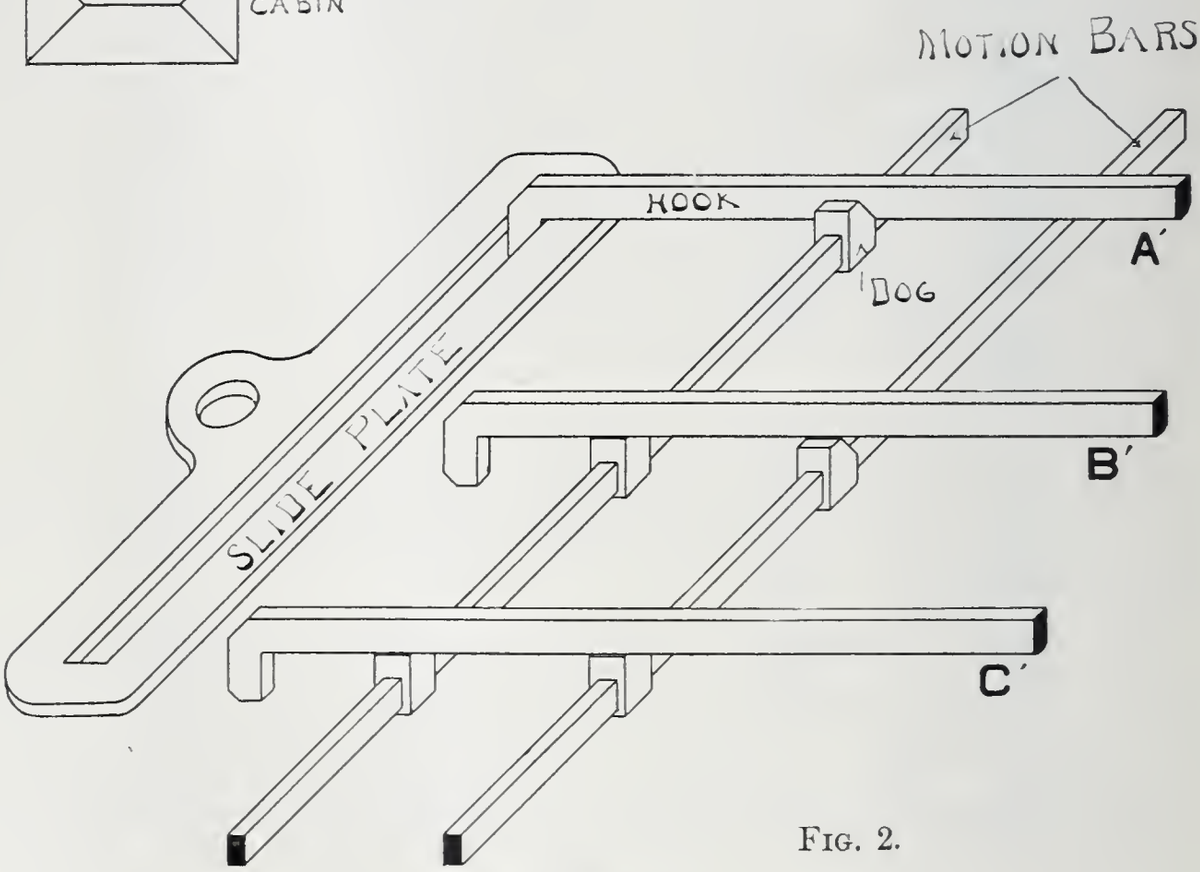


Fig. 2.

PLATE VI.

by the signal lever. The hook bars, it will be seen, are continuations of the signal wires $A,'$ B' and $C,'$ and the arrangement of the dogs is such that one hook bar, and only one, will be connected with the slide plate at the same time, while a change in the position of either or both of the switches will result in altering the connections between the slide plate and the several signal wires. In actual practice, signals A, B and C would be called by the same number that is given to the lever that operates them.

The use of selectors greatly complicates and increases the locking, although, as stated, it reduces the number of levers in a machine.

The necessity for a thorough and intimate knowledge of the mutual relations existing between the various devices used in interlocking, in order that important questions of detail may be intelligently decided, is therefore evident.

The plan of selecting which I have described is particularly adapted to signals which are operated by wire; when pipe is used as a means of connecting signals, a different kind of selector is to be preferred, and instead of being placed in front of the cabin it is usually located as near as possible to the switch which controls the action of the signal arms. It does not differ in principle from the wire selector, but bears little outward resemblance to it.

The *facing-point lock*, Plate VII, acts as a check on the performance of the switch. It consists of a round steel plunger working in a casting which is bolted to the tie immediately in front of the point of the switch, and may be located either inside or outside of the track, the latter arrangement being the best. A bar which is connected with the switch, works through the casting at right angles to the plunger and is provided with two holes very slightly exceeding in diameter (about $\frac{1}{16}$ inch) the diameter of the plunger, and at a distance from center to center exactly equal to the throw of the switch.

The interlocking on the machine is so arranged as to force the leverman to reverse the facing-point lock lever and thus lock the switch lever in the cabin and the switch on the ground before he can reverse his signal lever. The reversing of the facing-

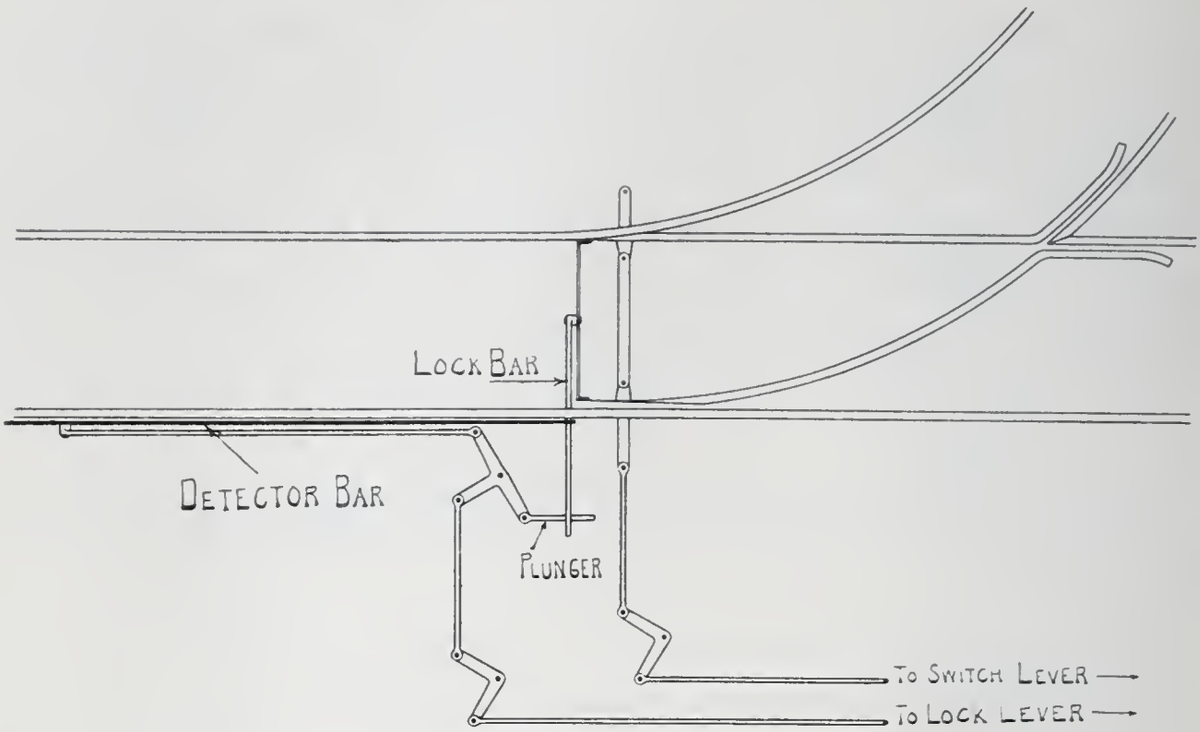


PLATE VII.

point lock lever should result in one of two things: It should, as stated, lock the switch if it is right and release the signal lever, or, if the switch should happen not to have completed its full movement, the lock plunger ought to impinge against the metal of the bar and, being unable to perform its full stroke, hold the signal lever in the cabin at the danger position. That which I have described is the common form of lock, but it has failed under certain circumstances, as, for instance, when a lever becomes disconnected from its switch. That is really the time for the lock to prove its value, but this form is deficient in the fact that the plunger will enter either hole of the lock bar. There are several ways of meeting this trouble and all of them involve additional expense, a reason which has so far prevented much from being done to effect a cure.

The *Detector Bar* is really a part of the facing-point lock arrangement and almost invariably accompanies it. Plate VII shows the method of combining the two in the ordinary manner.

The function of the detector bar is to prevent the movement of a switch when the movable rails are straddled by two trucks. In order to do this the bar must be slightly longer than the greatest distance between any two trucks on a train, which distance is now assumed to be always less than 45 feet, and it must rise high enough, when in the act of being moved, to certainly

strike any wheel which rests upon the rail before the bar has reached the center of the arc which it describes. It is supported on a series of arms which are pivoted and hung at their lower ends to the base of the rail. Thus the bar, when in one of its extreme positions, lies with its top about one-half inch below the top of the rail, and in the center of its arc should rise about three-quarters of an inch above the top of the rail.

I have shown you only the simplest arrangement of the detector bar, but many cases are met when it is extremely difficult to properly protect all of the moving rails in a track. This is particularly true as regards double slips with movable frogs, which require sometimes more than 240 feet in length of bars for each set.

A device called a *switch and lock movement* is sometimes used to combine the shifting of a switch, a lock and a detector bar by the operation of one lever. When this method is adopted the mechanism is so arranged as to follow a certain sequence of movement; first the detector is raised and the lock withdrawn; as soon as the lock is entirely clear the switch is moved, and during the last part of the stroke the bar is lowered and the switch again locked. While the switch and lock movement provides a perfectly safe plan under many conditions, it is, generally speaking, an inferior method to the one where the lock and bar are operated by one lever and the switch by an entirely separate lever. It should therefore be used with certain restrictions.

Broadly speaking, when the action of a switch and lock movements can be checked at the switch by a signal bolt lock, or at places where slow and infrequent train movements take place, the use of the switch and lock movement is warranted, otherwise it is not.

Switches may be successfully operated at a distance of 1,500 feet from the cabin, but not much farther, as it is desirable that the levers shall not be uncomfortably hard to throw, and, what is also important, all of the switches and signals should be within sight of the cabin whenever possible.

So far as I am able to judge, the future needs of interlocking in this country are a more just appreciation of its absolute necessity if safety to life and limb is to be secured in the opera-

tion of our railroads, and a wider knowledge of the fact that a properly interlocked plant may be handled at less cost and with many times the facility that is possible with hand-worked switch stands after the old fashion.

There seems to be little more to be done in the field of invention, for almost all devices connected with manual interlocking are satisfactory to a degree, and any improvements which we may hope for will probably be advances on things now existing. This is a somewhat daring statement, but is, I believe, warranted by the facts as we know them.

DISCUSSION.

Prof. L. F. Rondinella.—I have heard that in England they use the yellow semaphore arm quite frequently, because the color can be seen better. Is that a fact?

Mr. Paine.—I do not know whether they use it or not. I do not think the color can be seen better. I should think that it would be no better than red, if the proper shade is used, and the blade kept properly cleaned and frequently painted. The advantages of the yellow color are based on a different idea, *i. e.*, that it has no significance in signals at all.

Dr. Henry Leffmann.—Yellow has been considered by some authorities as the most brilliant color to the human eye. I think that whether or not yellow would be well suited in semaphore blades would depend on the landscape. Standing out against the blue sky, a yellow blade would probably be more conspicuous than any other color.

The President.—On the other hand, yellow blades against a background of plowed fields could scarcely be distinguished.

Dr. Leffmann.—It is perhaps a mistake that color was ever employed. To be able to judge the signals by their position only, would, I think, be an advantage.

XII.

FIRST PAIR OF HORIZONTAL TURBINES EVER BUILT WORKING ON A COMMON AXIS.

By Emile Geyelin.

Read June 1, 1895.

At the President's suggestion I am before you to-night to give you a short history of what I fully believe was the first pair of turbines working on the same horizontal axis, thereby utilizing the end pressure. These turbines I made in the year 1854, nearly forty-one years ago, as attested by the original agreement I here hold in my hands, duly signed and witnessed by the honored father of your former President, Mr. Trautwine.

Before entering into details, a short review of the history of turbines in general will, I trust, prove of some interest.

The word "turbine," meaning "turning on its axis," is old, though little used in the English language. Turbines, though very uncouth, have been used more than six centuries ago by the Moors in Spain, as Beliedor in his famous work on "Hydraulics" furnished actual drawings of some.

It was, however, the master spirit of the opening of this century, the great Napoleon, who, with a view to developing the resources of France, offered rewards and distinctions for the development of the turbine. This produced a Fourneyron, who gave us the beautifully designed outward discharge turbine bearing his name.

Again, later on, towards the year 1840, we have a Jonval, who conceived the use of the vacuum column in conjunction with the downward discharge turbine, thereby making the revolving parts more accessible and the local works much less costly.

Fortunate do I feel myself to have personally known these two distinguished men.

Fourneyron's labors were not for France alone. Bright minds on this side of the Atlantic followed in his footsteps. Who has not known of Uriah A. Boyden and James B. Francis, whose lives were largely devoted to the development of the Fourneyron turbine? Long will their names be honored for what they have done.

I trust it may not be out of place for me to state here, that, in their enthusiasm to attain the maximum possible result, they must have to some extent favored the use of a special coefficient in one eventful instance at Lowell, Mass., when by actual dynamometric tests it was reported that the results obtained came within 3 per cent. of perpetual motion.

Coming now to our subject-matter, namely, the making of the first pair of horizontal turbines to work on the same axis, I have to say that in the spring of 1854, forty-one years ago, there came to the Brandywine, near Wilmington, from Palitas, Mexico, Mr. James Prince, the owner of a cotton mill in Mexico. Mr. Prince informed his friends on the Brandywine that he was on his way to Manchester, England, to order an overshot water-wheel 100 feet diameter, for which he expected to expend $25,000. Mr. Prince's friend, Mr. Riddell, presented him to Mr. Alexis Du Pont, and Mr. DuPont, knowing the advantage of turbines as actually demonstrated in his own works by the writer, unhesitatingly recommended the use of turbines instead of the overshot wheels. The problem was certainly a bold one—to build a 140 horse-power turbine under 160 feet fall. However, studying the subject and making the necessary calculations, I agreed to make him a pair of horizontal axis turbines, connecting them to a countershaft by means of spur wheels, whereby the motion was transmitted, and a speed of 185 revolutions per minute attained, for which the charge was $2,300, less than one-tenth of what Mr. Prince expected to spend in England. The turbines were 11 inches in diameter, and made 1,850 revolutions per minute. Their action in Mexico was highly satisfactary, as several similar orders were sent afterwards.

Permit me to close by stating that one of our ablest engineers in hydraulic matters, Mr. Cartwright, reminded me not long ago that forty-one years ago, while an apprentice at the works of I. P. Morris & Co., he worked on this identical turbine.

DISCUSSION.

Mr. John C. Trautwine, Jr.—Would it not be well to describe the design in a sketch on the blackboard, so that the members can get an idea as to its meaning?

[Mr. Geyelin explained the design in detail with the aid of a blackboard diagram. In describing the mechanical parts he stated that the pinion was made of scrap iron. It, with the turbines on the same steel shaft, made 1,850 revolutions per minute, and geared in a wheel which made 182 revolutions.]

Mr. Trautwine.—I understand that the cylinder below the turbine with draft tube acts very much like the reverse of a chimney—a column of air moving up the chimney and a column of air moving down the draft tube.

Mr. Geyelin.—This vacuum depends upon the height or rather difference of level.

Mr. Trautwine.—Precisely as a tall chimney gives a better draft than a short one.

Mr. Geyelin.—This can hardly apply, because the principle is different. If you stopped the tube short of plunging in the tail race water, the whole effect would be lost.

Mr. Trautwine.—So if you closed the top of your chimney the effect would be lost.

Mr. Geyelin.—I wish to say, gentlemen, that the use of the column of vacuum on turbines was thought of before I brought the Jonval turbine to this country, but it was in rather a crude shape. It was invented by a man in Ohio in 1848, and when I came to this country in that year, the principle of the vacuum was known here. There are quite a number of the inward discharge and upward discharge wheels. They are generally immersed however, and the advantages of draft tubes are generally recognized.

A Member.—Is it possible to govern the action so as to get a uniform motion, as with a steam engine?

Mr. Geyelin.—We have at Niagara Falls an electric governor, which regulates very satisfactorily. There we have what is called three inverted turbines—the water is admitted from below.

Mr. A. Falkenau.—Is the gate around the wheel, or are there a series of gates?

Mr. Geyelin.—One gate, a cylinder gate, made very heavy, so that it can thoroughly close the turbine. Each gate weighs 3,000 pounds alone, but it is counterbalanced and works perfectly easy.

A Member.—I would like to ask Mr. Geyelin whether the length of the draft tube in any manner affects the operation of the turbine.

Mr. Geyelin.—If it is mechanically correct, there is no trouble at all about it; but sometimes, through carelessness, the air is admitted and the vacuum is destroyed. But as long as it is mechanically correct it acts well, and it matters not whether it is run horizontally, inclined or downward, the action is the same.

Mr. Trautwine.—Does the length or depth of the draft affect the working? I understand from your answer that it makes no difference in the efficiency of the turbine.

Mr. Geyelin.—You can make use of a draft tube for 25 or 28 feet difference of level.

Mr. Birkinbine.—Mr. Geyelin's acquaintance with water wheels carries him back far enough to have known what people had to depend upon before the idea of using the draft tubes was suggested. To-day, by the use of draft tubes, practically all wheels, whether they are horizontal or vertical, are so placed that they are readily accessible for inspection or repair. The first time I met Mr. Geyelin was during a test of turbine wheels, in which he came out ahead, and put the wheels in at the Fairmount Water Works. The test was not made by the dynamometer as now, but his wheel was given a certain volume of water, and had to lift a certain weight to a given height.

Mr. Geyelin.—I remember distinctly the trouble Mr. Birkinbine's father had with the foundations at Fairmount; much would be avoided to-day by applying that same principle of draft tube.

Mr. Falkenau.—I would like to ask Mr. Geyelin in regard to the question of efficiency of wheels under different gate openings.

Mr. Geyelin.—It depends mainly on the style of gate; some gates give better efficiency than others.

A Member.—Do you know the Pelton wheel?

Mr. Geyelin.—I really have little knowledge of it, except of some tests which have been made. I have seen some descriptions of tests made which seemed to have given remarkably good results on very high fall. That question came up as regards the turbines for the Niagara Paper Co. The Pelton people had gone to great expense and had some tests made at Holyoke, yet the results were not satisfactory to the Company at Niagara, as they concluded that they would not try the arrangement there. In the western country—in California—the Pelton people have been very successful with their turbine; very high falls are in use there—from 700 to 1,200 feet.

XIII.

THE PHILADELPHIA AND READING COAL STORAGE PLANTS.

By William D. Beatty, Active Member of the Club.

Read June 15, 1895.

In order to provide for the demands of the coal trade, it has been found necessary to store coal in large quantities, in order to be ready for emergencies. The mines, as a rule, work only part of a week, and the further possibility of strikes, flooding of the collieries, blockades and various other causes, make it necessary to have a large supply on hand to meet the demands which may be made.

There are two general methods of coal storage: (1) The hillside system, generally situated in the mining regions; and (2), what may be called the level-floor system, generally located at or near the shipping points.

(1) In the hillside system large bins are constructed on the slope of a hill and a dumping track led along the top of the slope. The coal is dropped from the cars on the dumping track and rolls down the hill till stopped by the front of the bin. From the front of the bin a series of plank run back horizontally till they strike the slope of the hill, thus helping to arrest the coal and forming the beginning of the coal pile.

It is generally reloaded by an underground chain conveyor. This conveyor runs along the whole front of the storage plant, and is operated by a rope drive. The coal is led into the conveyor trough by men with short lengths of sheet iron, and the conveyor then carries it to a central hopper. Here another conveyor picks it up and carries it up an inclined plane to a tower where it is screened and loaded into cars. Both the Schuylkill Haven and the Mahanoy City plants of the Reading Company are operated on this system. The Schuylkill Haven plant was first operated by dump cars running back into the coal piles and then forward to a reloader track on a wharf constructed at the foot of the slope. From the edge of the wharf the coal was

dropped through a screen and chute into the cars. This system is still used at Schuylkill Haven in connection with the later one.

(2) Level-Floor Systems.—For many years, Port Richmond, Philadelphia, has been a coal-shipping point. At first the coal not immediately needed was simply dumped to the ground and, when wanted for shipment, loaded by hand into wheelbarrows, wheeled up a plank to the vessel and dropped into the hatch.

In 1887, a trimming machine for storing coal was put in, and was followed the next year by a reloading machine. There resulted at once a great saving in the cost of handling.

At present the coal around the trestles is reloaded, either by a chain conveyor or by portable conveyors. The first consists of an endless chain, run by power and provided with scrapers or flights. This chain runs in a long trough extending along the front of the coal piles. The coal is shoveled into this trough by a gang of men, or, when the supply gets too far away, dumped in by wheelbarrow, carried by the chain to a hopper pit and from there raised by another endless chain and buckets to a tower. From the tower it is dropped by a chute into the cars and carried to the loading piers, where the dirt is screened out and the coal dropped into the vessel. The greater part of the coal stored around the trestles is reloaded by the portable conveyors. There are four of these machines in use at present, three of which are of the same general type. They consist of a long boom with a chain carrying a bucket, and supplied with gearing for propelling themselves along the track. They carry their own engines and boilers, which also serve as counterweights. The buckets are of the clam-shell style, opening and closing automatically, and have a capacity for lifting, some of them a ton, others a ton and a half, at one time. The machines are stored on a side track and when needed propel themselves to the desired storage pier, where they pick up the coal anywhere within a radius of about thirty feet, and load it into cars on an adjoining track. The vertical motion of the bucket, the horizontal revolution of the boom, and all the other movements of the conveyor are controlled by levers enclosed in the machine. All levers are worked generally by one man, in some cases by two. The fourth machine

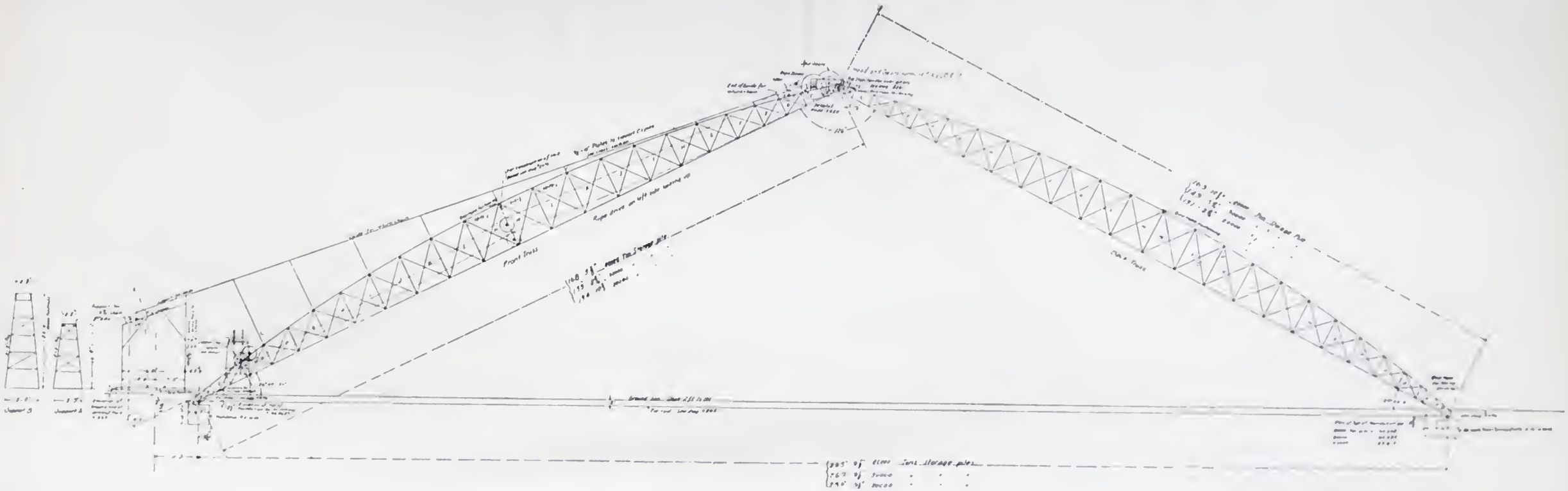
is supplied with a bucket lift consisting of an endless chain working in a vertical plane and carrying a series of small buckets. The coal is lifted by the buckets and dropped into a chute leading to the cars. All these machines shift their own cars.

The present storage plant known as Pier 24 is an outgrowth of the trimming machine put in in 1887. At present it consists of two trimming machines and one reloader, with a storage capacity of 80,000 tons. The coal is dropped from the cars into a hopper where it is picked up by an endless flighted chain running to the top of a boom attached to a guyed mast. The position the coal will occupy in the pile is determined by the raising and lowering of the boom, and its position horizontally. The coal is still further guided by a loose piece of sheet iron, placed where it catches the coal as it comes from the upper end of the slope.

The coal is loaded back into the cars by a pivoted ground conveyor or reloader, consisting of a flighted chain running around a metal frame. The original frame was of timber with an iron wearing plate for conveying the coal, but was replaced by the present one a year or two ago. All chains in this plant are run by power, but the reloader itself is moved by hand. This necessitates the feeding of the machine by hand, as it cannot be worked economically or safely otherwise. If it is not placed near enough to the foot of the pile, it will not pick up the proper amount of coal. If it is placed too close, the coal is liable to slide and bury the machine. As the foot of the pile is continually shifting, the necessity of the hand-feed is evident. Therefore the coal is shoveled by a gang of fifteen or twenty men on to the wearing plates, carried by the flights on the endless chain to a hopper, thence by another endless chain up an incline to a tower, where it is screened and dropped by a chute into the cars.

All the systems at Port Richmond above described are operated by private parties.

The new plant now being constructed on the Dodge Coal Storage system occupies about fifteen acres in the neighborhood of the present coal piers at Port Richmond, and will consist of six piles of coal, two of 20,000 tons each, two of 30,000 tons each and two of 40,000 tons each, arranged as shown on the general plan. The total storage capacity will thus be 180,000 tons.

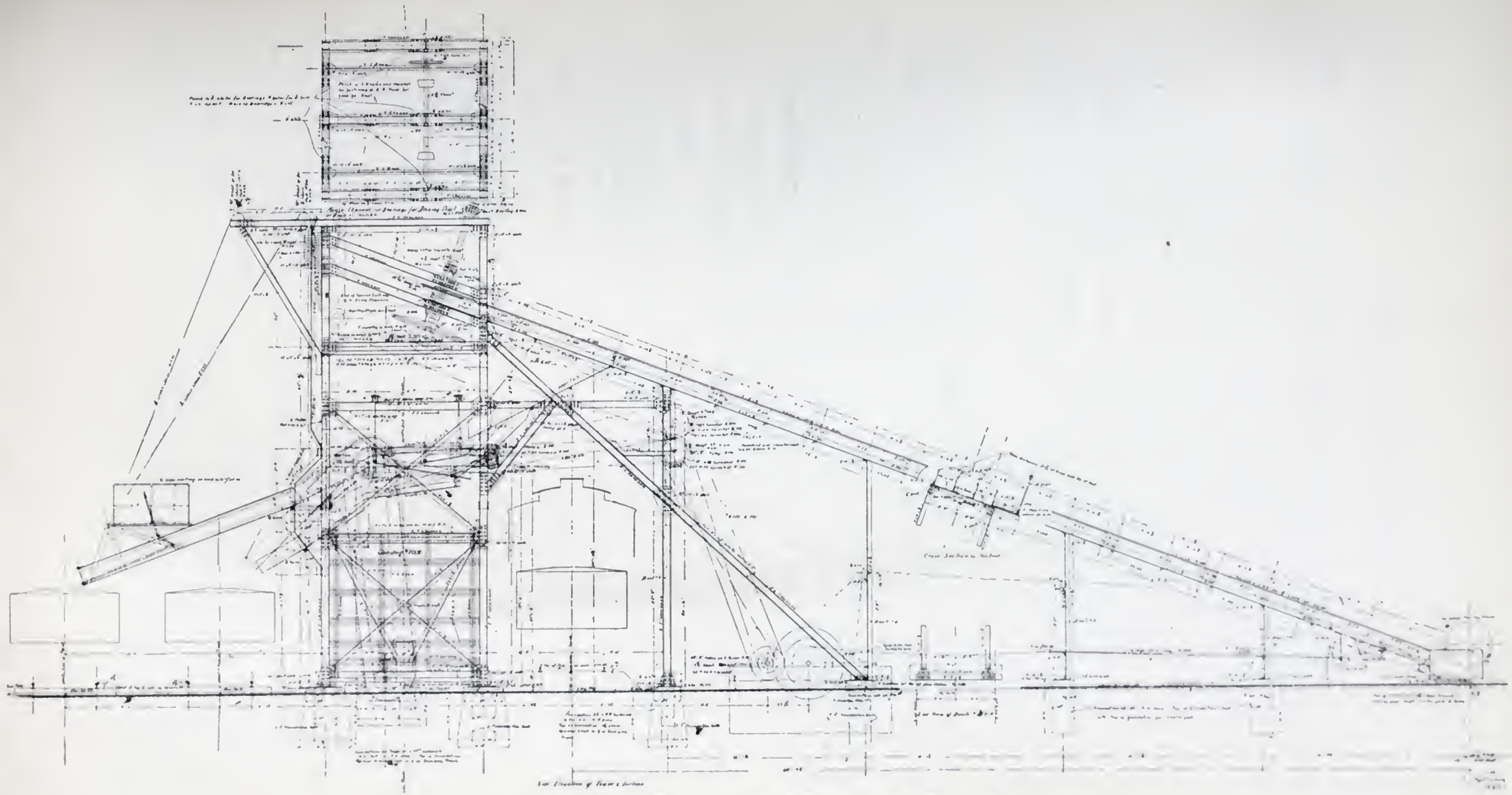


Side Elevation of Trimmers.

In this system the coal is stored by a chain conveyor carried by a braced truss, constituting a trimming machine or trimmer. The apparatus for reloading consists of a pivoted ground conveyor with a flighted chain, an inclined plane carrying troughs for lifting the coal and a tower for screening and delivering to the cars. Generally, in this system, two trimmers and one reloader constitute a group, but in this case the two groups are each composed of three trimmers and two reloaders. There are thus six trimmers and four reloaders with inclines and screening towers used in the operation of this plant.

The trimmers are respectively 236′ 9$\frac{1}{8}$″, 269′ 9$\frac{1}{8}$″, and 295′ 9$\frac{1}{8}$″ *C* to *C* of end pins, and span the coal piles at or near the natural angle of repose. The natural angle for coal in large quantities, as stored in practice, is about 27°, which is the angle at which the trimmers are placed. The computed dimensions of the piles themselves are: diameter 232.4′, altitude 59.2′, for the small piles; diameter 265.4′, altitude 67.7′, for the medium sized pile; and diameter 291.4′, altitude 74.4′, for the large pile. The trimmers are thoroughly guyed by $\frac{5}{8}$″ and $\frac{1}{2}$″ wire cables and are hinged at the top. Half the structure acts simply as a brace to support the other half and is tied to it at the bottom by tension bars. The back truss is free to slide at its lower end in order to allow for expansion.

The coal to be stored is run in on the dump track and dropped into a hopper. The hopper pit consists of a steel tank embedded in brick masonry, and encloses the lower end of the conveyor trough. Above this timber joists and planking lined with sheet iron form the hopper. Through a small door in the hopper, controlled by an outside lever, the coal drops into the conveyor trough, where it is picked up by the flights on the chain and carried to its position in the pile. This position is determined by a sliding sheet 12″ wide, which winds on a drum at the foot of the trimmer and forms the bottom of the conveyor trough. This sheet is worked by hand gearing, and its upper end is thus made to follow the receding apex of the coal pile, continually feeding the pile from the apex, and further, allowing the coal to drop but a few inches. The conveyor chain, having deposited its coal, runs on to a sprocket wheel at the head of the trimmer, then



Side Elevation of Tower and Incline.

back along the top on guide angles supported by steel frames bolted to the trimmer, to an idler tower at the foot, whence it runs vertically to the hopper pit and up the trimmer again.

When the coal is wanted for shipment the reloader is moved to the edge of the coal pile and the chain set in motion. The flights on the chain then pick up the coal and carry it up the incline to chutes leading to shaking screens in the tower, where it is screened and loaded into the cars. By means of a screw and lever the shaft on the reloader carrying the head sprocket wheel may be moved forward or back, thus keeping the chain always at the proper tension.

The conveyor for reloading the coal consists of a steel frame with a wearing plate 18″ wide, bolted on the outside, so it can be replaced when necessary. It swings on a $4\frac{15}{16}''$ pivot, and travels on a series of circular rails 35 pounds per yard, small wheels for that purpose being attached to the framework. The extreme sweep of the reloaders is 231′ 4″ for the large ones and 201′ 4″ for the small ones, and the total arcs described 214° and 215° respectively. The reloaders are moved bodily by means of 2-1″ wire cables attached to drums at one end, and passing over guide wheels to anchors at each end of one of the circular rails. Each cable winds on a drum, and as one drum winds up its cable the reloader swings in the direction of the corresponding anchor, the other drum meanwhile unwinding its cable. The tendency of the cables to sag is prevented by carrying them over the reloader in $1\frac{1}{2}''$ gas pipe.

The conveyor chain travels on the wearing plate to the foot of the incline, then up one side of the incline in a trough to a sprocket wheel on the head shaft in the screening tower, thence down the other inclined trough and around the other side of the reloader to the starting point. This conveyor chain is continuous over both reloader and incline, thus saving one dump, with its consequent chance of breakage. It is guided by horizontal wheels at the short end of the reloader, and by holding-down wheels at the point of junction of the horizontal and incline, thus keeping the flights in direct contact with the coal. On both the trimmer and the reloader there is a guard over the chain, which serves still further to prevent the flights mounting the coal at any point.

The bodily movement of the reloader and the movement of the chain are both controlled from a platform near the reloader pivot. Two $\frac{5}{8}''$ wire ropes pass over spools on a hollow vertical shaft at this point and run back under the incline, the one to the lever controlling the reloading drums, the other to the lever controlling the chain movement. The man stationed on this platform thus has absolute control of the reloader movements, and is in the best position for directing those movements. It is his business to keep the machine in the position at the moving foot of the coal pile to obtain the maximum efficiency, and he must also be ready, in case of a sudden fall of coal, to get the machine out of the way, in order to prevent its being buried, with the probable breakage of some of the machinery.

The screening tower is composed of built steel members firmly braced and riveted together. The lower part is enclosed, forming a dust pocket, and the upper part carries the screens and the head shaft and gearing for the reloader chain. To the tower are also attached the two reloading chutes with the gearing for their manipulations. Just outside of the tower is the dust elevator, which consists of a steel casing enclosing a bucket lift for the screenings.

The screens are of the shaking type, and are double, the top one separating the sizes, the lower one taking out the dirt. The mesh of the top screens in the different towers varies according to the size of coal handled, but the screens themselves may be changed in a short time. They are suspended by wrought-iron links, and are worked by eccentrics on a shaft connected by chain belting with the main shaft in such a way that the oscillation of the screens takes place whenever the reloader chain is working. The top screen leads directly to the long chute, and coal passing over this screen is loaded into cars on the second reloading track. The smaller sizes drop to a pan leading to a second screen, and are loaded from the small chute to cars on the first track. Cars on both tracks can therefore be loaded at the same time. There are two chutes leading from the incline to the screens, and if desired the coal may be led through the lower chute directly to the lower screen. The dirt passing through the lower screen drops into the dust pocket, which has a small opening at the bottom leading

to the dirt elevator. Here it is picked up by the buckets on the elevator and loaded from a chute into cars. All loading chutes are hinged and counterweighted so they can be drawn up out of the way.

The power is furnished by four independent engines, supplied with steam from a central boiler house, each engine running one reloader and either one or two trimmers. The boilers, two in number, are of the horizontal tubular type, 6 feet diameter by 20 feet long, and are calculated for a working pressure of 125 pounds per square inch. They are provided with McClave grates and are intended to burn screenings with the aid of steam blowers.

The engines are of the simple Buckeye type, 14 inches x 20 inches, and are rated each at 100 horse-power. Steam is conveyed to the engines in pipes, 6 inches in diameter from the boiler house to the near engine houses, and 4 inches in diameter beyond. They are carried in boxes stuffed with asbestos packing and supported by steel trestle bents.

Power from the engine shaft is extended by means of a flange coupling to a shaft $4\frac{7}{16}$ inches in diameter, having a speed of 200 revolutions per minute. This shaft carries a fly-wheel, sheaves for the rope drive for the trimmer, and a pinion with a jaw-clutch. The trimmer sheaves are controlled by friction clutches and levers, and are operated in the engine room. The pinion on this shaft engages with a gear-wheel on a $3\frac{15}{16}$-inch jack-shaft, having a speed of about 72 revolutions per minute. This shaft carries the gears for operating all reloader movements and the car haul.

The trimmer chain has a speed of 200 feet per minute, and is operated by a rope drive which passes from the sheaves in the engine room over guide wheels to the head of the trimmer and back again, thus applying the power to the trimmer chain from the top. The levers are so placed that either one or both trimmers may be operated at the same time or both may be thrown out of gear.

The drums for the reloader movement are 30″ in diameter, and are set on a shaft having a speed of 9.8 revolutions per minute. They are set in motion by pinions with friction clutches on the

General View of Coal Storage Plant at Port Richmond, Philadelphia.

jack-shaft. The clutches are controlled from the reloader platform by a lever, and are so placed that when one drum is thrown into gear the other one is thrown out, or the lever may be so placed that neither drum is in gear.

The reloader chain is operated from the jack-shaft, where it is controlled by a lever and friction clutch. By means of chain belting and two intermediate shafts, power is finally transmitted to a counter-shaft in the tower on which are placed two bevel pinions, either of which engages a large bevel wheel fastened to the head shaft of the reloader. This shaft is $4\frac{15}{16}''$ in diameter and has a speed of 19.6 revolutions per minute, giving the reloader chain a speed of 200 feet per minute. As in the case of the trimmer chain, power is applied to the reloader chain from the top.

The first intermediate shaft mentioned above is connected by chain belting to a shaft carrying the eccentrics for working the shaking screens. This shaft has a speed of 100 revolutions per minute. The screens are thus at work at the same time as the reloader chain.

The dust elevator is operated by a shaft and sprocket wheel at the top, connected with a counter-shaft directly under the intermediate shaft above mentioned. The elevator shaft is $2\frac{11}{16}''$ in diameter, having a speed of 36 revolutions per minute, and its movement is controlled by a friction clutch and hand lever on the counter shaft.

The counter-shaft driving the elevator is connected with the jack-shaft by a $6''$ crossed belt and also transmits the power for raising and lowering the long chute. Through reversible bevel gearing in the towers, power is finally transmitted to a winding-drum carrying a chain attached to the lower end of the chute Each bevel wheel is worked by a friction clutch, both of which are attached to a lever operated by a man stationed on a platform near the lower end of the chute itself. This man also controls a lever for opening and shutting the door of the chute. By this means he keeps the chute full of coal all the time, thus keeping it in a compact mass and avoiding breakage, and, further, raises or lowers the chute as desired.

The small loading chute and the elevator chute are worked by hand.

The car-haul drums receive their power from the jack-shaft by means of spur gearing, and are operated by cone friction. One end of a wire rope is attached to the cars to be shifted, while the other end passes over a snatch-block firmly anchored at the track level, and is finally wound on the drum. The drum shafts have a speed of 9.8 revolutions per minute. The gearing is so arranged that any part of the machinery can be operated independently of any other part.

There are other conveyor systems in use on the lines of the Philadelphia and Reading Railroad, generally for small plants. The coaling station at Wallace and Ninth Streets, Philadelphia, which lifts 400 to 500 tons of coal daily, is run on the C. W. Hunt system. The conveyor in this system consists of a series of buckets linked together and suspended on pivots. The pivots also carry small flanged wheels similar to ordinary railway wheels, which travel on a prepared track. The buckets are continually in an upright position, hence the chain may be run in any desired direction, this direction being governed by the track. The chain is composed of heavy wrought-iron links and is driven by pawls pushing along the chain, instead of by sprocket wheels. The speed of the chain is very low, the capacity of the plant being determined by the size of the buckets. The first cost of these machines is somewhat more than that of other systems, but the running expenses are low, as, the friction being very small and the speed of the conveyor low, it takes very little power to run it. Probably 4 or 5 horse-power is sufficient to raise the coal at the Ninth Street plant and to lift the ashes beside.

The hillside plants are used as distributing points, so that coal may be shipped in any direction when needed. They are cheaply constructed in a locality where waste land may easily be obtained, but they are open to the serious objection that the coal is very roughly handled, and there is a heavy loss from breakage. Sometimes, also, the grades are excessive, causing a heavy charge for haul. The first cost of the plant, including trestles, bins, conveyors, and power, is not nearly as high as in the later systems, but the cost of maintenance is greater. In spite of the comparatively high first cost of the new plant, the average price per ton for dumping and reloading is expected to be only

about one-half that of the present hillside system, not, however, allowing for the difference in the cost of location.

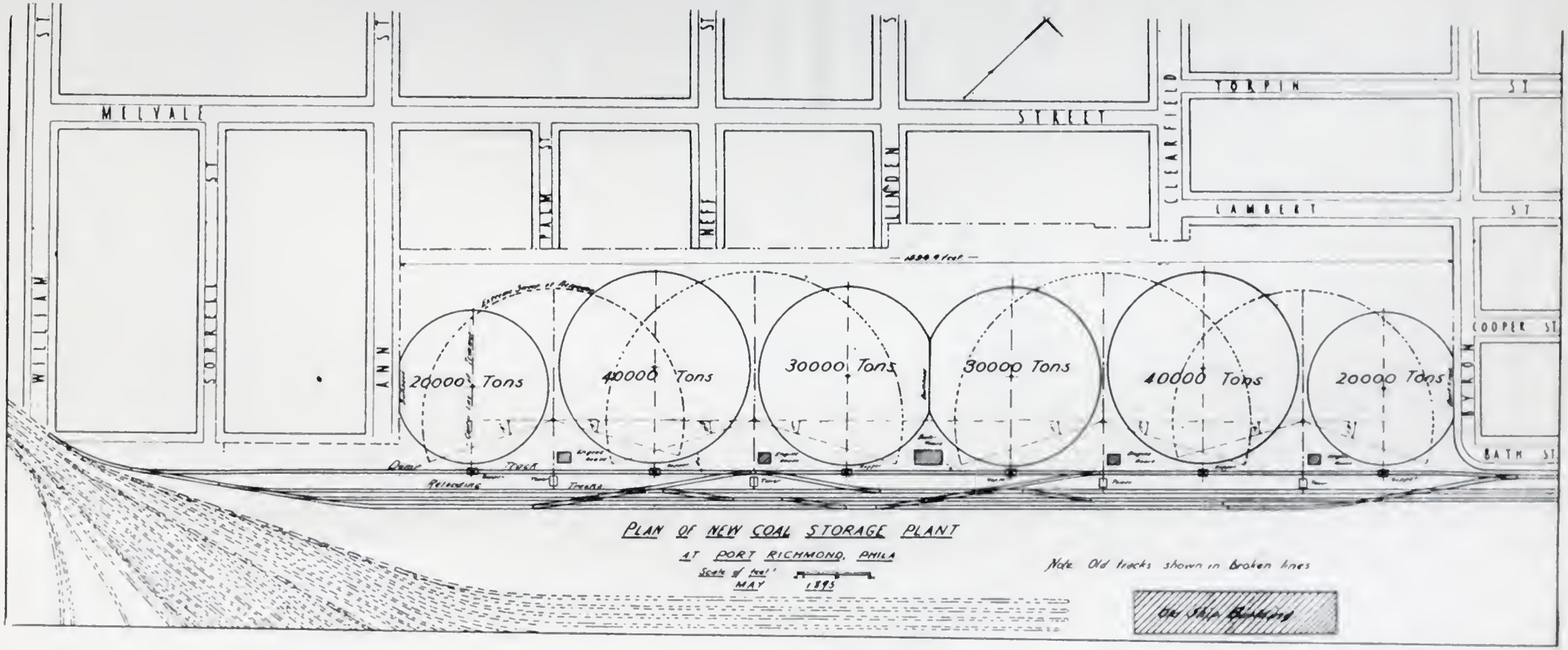
On the level floor systems above described it would seem, at first sight, much cheaper to dump the coal directly to the ground, rather than to carry it out by a chain conveyor, but some of the coal dumped to the ground must be trimmed by hand, the breakage is considerable, and the maintenance charge for the trestles is a good deal, hence the average cost per ton dumped is much less when carried out by the conveyor than when dumped to the ground by the old method.

For reloading, the old chain conveyor fed by hand can raise coal very quickly, but the large number of men required to feed it makes this a comparatively expensive method.

The portable conveyors are very cheaply operated and, if care is taken in their manipulations, should give very good results. They are liable to break the coal to a certain extent, when the two halves of the bucket come together, and also if the bucket is held too high when the coal is dropped into the cars, but with a careful engineer this can be largely reduced. The breakage is partly offset by the fact that the coal is carried in a large compact mass. One machine, built by the McMyler Manufacturing Company, has loaded 1,000 tons of coal in a working day of ten hours, but the probable average capacity is about 700 or 800 tons, providing the cars are furnished promptly.

The old pivoted conveyor has loaded nearly 1,600 tons in ten hours actual working time, but the average capacity is probably about 900 to 1,000 tons. The cost of trimming per ton in this plant does not vary much from that of the new plant, but the cost of reloading is much greater on account of the necessity for feeding by hand, which much more than offsets the greater interest charge in the new plant.

The new plant has a nominal capacity of three tons per minute, but the experience of similar plants has been that, including delays from breakdowns, stoppage to get out the dust, delay in shifting, and the usual troubles that occur in any large plant, 1,000 to 1,400 tons lifted and the same amount dumped constitute a fair day's work. The higher figures are for the later plants constructed on this system, and there is every reason to believe



PLAN OF NEW COAL STORAGE PLANT

AT PORT RICHMOND, PHILA

Scale of feet

MAY 1895

Note Old tracks shown in broken lines

On Ship Building

that the Richmond plant will at least equal if not exceed those figures, but even taking the low estimate, there will be a large saving in the cost of handling over present methods, when the new plant goes into operation. Besides that, it furnishes its own car haul, reducing the locomotive service to a minimum; and, by the continuity of the reloading system, and by having a very small drop for the coal at transfer points, reduces the waste from breakage to a very small amount. There will also be a large saving of fuel, but the plan of burning screenings may of course be applied to other power plants as well and is not essential to this system.

These plants have all been discussed on the supposition that cars are supplied without interruption. Practically, this condition does not obtain at all. There may be business enough to keep the plant busy night and day and, on the other hand, there may be no business at all. It may even happen that exactly the same coal which is stored in the morning is reloaded in the afternoon. Hence, the actual working cost of the plant is a very variable amount, but figuring on past records of cost and allowing a fair estimate for the working capacity of the plant, it is expected that a saving of $35,000 to $40,000 a year in the cost of handling will result from the operations of the new plant.

The writer desires to express his obligation to the Dodge Coal Storage Company for the loan of illustrations and for general information furnished.

DISCUSSION.

Mr. Falkenau.—What has been the experience in regard to the effect of coal dust on the wear of the bearings in apparatus of this kind?

Mr. Beatty.—I have not heard of any trouble on this score. The dust collects in the coal pocket and affects only the dirt elevator. The latter not being a complicated apparatus, I do not think that the dust would give much trouble. If it should, the matter could be easily remedied.

A Member.—Do I understand that this system is used for anthracite coal only?

Mr. Beatty.—The plant just described is used for anthracite coal only, but the system is applicable also to bituminous coal.

Mr. C. W. Hunt.—It was with a great deal of pleasure that I received the invitation to attend this meeting, especially as I take great interest in this line of work. I have been much impressed this evening in regard to the magnitude of the machinery now required to do such work. When on a tour of Philadelphia and the Eastern States in the year 1872, I do not remember one single instance of a plant for handling coal by machinery costing as much as $2,000. To-day this sum would be a mere trifle towards paying for the minor fixtures around the yard. It has been very interesting to me to have seen the perfect representation that we have had and the accompanying description. The particular line of machinery in which we have operated has been slightly different from that shown and it is intended more for the unloading of vessels and work of that character.

Mr. James M. Dodge, of The Dodge Coal Storage Company.—I do not know that there are any special remarks I wish to make on this subject, as Mr. Beatty has covered the ground very thoroughly. I was much interested in listening to his paper. As he did not dwell upon the speed with which the apparatus handles coal, I might say that the six trimming, or piling, machines we have just erected at Port Richmond are each capable of storing coal at the rate of five tons per minute, or if all were running at once, thirty tons per minute could be put in stock. When it comes to reloading this coal, any one of the four reloaders, operated by one man, is capable of delivering between five and six tons per minute to the cars to be loaded. To get an idea of what this means when contrasted with the primitive method of reloading coal with shovels and wheelbarrows, I would say that 125 men using shovels and wheelbarrows, and having a space of 35 feet in length in which to dump the coal into one of our old conveyors running along the piers at Port Richmond, could only deliver to the conveyor 1¼ tons per minute. On this basis, one man operating a reloader in the new plant, would be more than equivalent to 500 men trying to do the same work with shovels and wheelbarrows.

Another point of possible interest, is that in the development

of this business we had to assume a great commercial risk, as we were not only obliged to guarantee a handling capacity of a certain number of tons per minute, but were also under agreement to make our installations "satisfactory." This term, as all engineers know, is construed very liberally by the purchasers of machinery, and so large were the amounts involved in these contracts, that should we, in the earlier days, have failed to come up to the broad meaning of the word "satisfactory," we would have been commercially ruined. All concerns that undertake the development of large enterprises involving special designs and more or less experimental, are necessarily obliged to take a jump in the dark. Fortunately, we have met with success in our undertaking.

Mr. Chas. Piez.—I wish to call the attention of the meeting to a certain modification of the Dodge Coal Storage System. It was found after developing this system to what was considered something near perfection, that two or three other considerations came up which completely upset all previous calculations, and made it necessary to change the design. These considerations were, first, the deterioration which coal undergoes when exposed to the open air for a long period. This deterioration in value is due partly to a change in the appearance of the coal. Coal, after having been exposed for a long period becomes rusty—loses its lustre—so that the selling price is very materially affected, amounting to as much as $1.00 to $1.50 per ton. Again, it is found that coal after long exposure disintegrates and becomes reduced in size. Lastly, in this latitude the coal, if left uncovered, is found to freeze to a solid mass, and large gangs of men are needed to break up the coal to feed it to the reloader.

About a year ago we were asked to design a plan for the Lehigh Valley Railroad, to be located at West Superior, and owing to the severe winters in that locality we were obliged to arrange a plant that could be suitably housed.

(Mr. Piez gave an interesting description of this plant, illustrating his remarks by lantern views.)

Mr. Harrison Souder.—I would like to inquire if any one present can give us some account of a plant which I think has been recently constructed at Cleveland or Buffalo, for loading

coal into ships, the cars being carried up an incline, and the coal being allowed to slide into the hold of the vessel through chutes.

Mr. Dodge.—My impression is that such a plant is located at Ashtabula, Ohio. The car having been conveyed up an incline, is turned completely upside down, the contents dumped into the hold of the vessel, and continuing its revolution the car is again brought to its original level. The troublesome feature I believe in this connection is the arrangement of suitable clamping devices for cars varying considerably in size.

Mr. Falkenau.—I would like to ask Mr. Dodge whether by that system the coal would be likely to be considerably broken up.

Mr. Dodge.—There is a considerable difference of opinion on this point. Personally, I believe in loading coal in a moderate stream, and under proper regulation, by engaging men who will give the proper attention to gates. Some persons interested in the coal business claim, however, that if coal is discharged in very large masses the breakage is less than would result by loading at a moderate stream. The only way in which the question can be definitely settled would be by actual tests on a large scale, and such tests are not likely to be made for some years to come.

Mr. Hunt.—On one occasion I canvassed the whole coast of the United States from Bangor, Maine, to Washington, and had interviews with all coal operators large and small. Curiously enough, expressions of opinion seemed to be very nearly equally divided as to the relative loss occasioned by dumping in carload lots and by barrowfuls.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, April 6, 1895.—President George S. Webster in the chair. Seventy-four members and visitors present.

Mr. J. Chester Wilson suggested that in order to please everybody interested in our new City Hall, it might be a good plan to have the statue of William Penn mounted so as to revolve, and moved by gear wheels and clockwork so that it would face all points of the compass twice in twenty-four hours. That as an additional convenience permanent marks might be placed at the fixed base on the north, east, south and west points, and marks on the revolving base, ninety degrees apart, so that when these marks come opposite every three hours, the time of day would be indicated. Mr. Wilson illustrated his proposal with a blackboard sketch.

Mr. Hermann S. Hering exhibited, and briefly described, a set of diagrams and tables, showing the results of a very complete series of electric railway tests recently made by him in the city of Baltimore.

Mr. F. H. Newell, in charge of the Division of Hydrography of the U. S. Geological Survey, read a paper, illustrated by lantern slides, on "Methods and Results of Stream Measurements by the United States Geological Survey."

The subject was discussed orally by Messrs. John E. Codman, John Birkinbine, Rudolph Hering, John C. Trautwine, Jr., and A. Falkenau, and at the conclusion of the discussion a vote of thanks was extended to Mr. Newell for his kindness in presenting this matter to the Club, and to Mr. Birkinbine for his influence in bringing Mr. Newell to Philadelphia.

Regular Meeting, April 20, 1895.—President George S. Webster in the chair. Seventy-two members and visitors present.

The paper of the evening, on "Electrical Heating," was presented by Mr. J. Chester Wilson, who illustrated his remarks by blackboard sketches and models of many of the devices referred to.

An oral discussion followed, participated in by Messrs. G. S. Webster, Carl Hering, C. W. Pike, James Christie, G. M. Sinclair, A. Falkenau and Prof. H. W. Spangler.

The Chairman of the Information Committee announced that it was the intention to have, in the early fall, a number of informal talks on electrical subjects, for the special purpose of making fundamental terms and methods clear to members in other branches of engineering, where a limited knowledge of electricity is daily becoming more necessary. These would probably be held on the Saturday evenings between Club meetings, and would probably be followed by more technical papers on special electrical subjects. This plan was quite fully discussed, and, by vote, approved by the meeting.

The President announced that on the evening of Tuesday, 23d inst., there would be a special meeting of the Franklin Institute, at Association Hall, to inaugurate the project for a new building, and that tickets for this meeting could be obtained at the office of the Institute.

Mr. John C. Trautwine, Jr., stated that it might be possible that this building

could be arranged so that other technical societies besides the Institute might occupy special quarters, and use its meeting rooms, and that if such arrangements were made, the Club might become practically interested in it.

Regular Meetings, May 4, 1895.—President George S. Webster in the chair. Seventy-two members and visitors present.

Mr. William H. Dechant read a paper on "Coffer-dams."

An oral discussion followed, in which Messrs. Trautwine, Ott, Smith, Webster and Leslie took part.

A paper by Mr. James R. Maxwell (non-member) on "Railway Construction in the Peruvian Andes" followed, which was discussed orally by Messrs. Webster, Birkinbine, Dahlgren, Livingston, Christie and Webb.

Business Meeting, May 18, 1895.—President George S. Webster in the chair. Seventy-two members and visitors present.

The tellers reported that Messrs. Richard Gilpin, Edward B. Ives, Stewart A. Jellett, Fred. H. Blake, Raymond Walton Smith, and William Seaton, had been elected to Active Membership in the Club.

The resignation from Active Membership of Mr. Jacob H. Yocum was presented and accepted.

The Secretary announced the death of Mr. Eckley B. Coxe, Active Member, on May 13th, and upon motion the chair was authorized to appoint a committee to prepare a suitable memorial.

Upon motion, a unanimous vote of thanks was tendered to the House Committee for the efficient manner in which they had managed the renovation of the Club House.

The Secretary read a communication from Mr. Carl Hering, giving particulars with regard to the electric heating of the Vaudeville Theater in London, which was referred to in the discussion at the last meeting.

Mr. Joseph Kemper read a paper on the "Wreck of the Connersville, Indiana, Bridge and its Temporary Repair," illustrated by a series of lantern slides.

Mr. C. L. Prince exhibited, by means of the lantern, and briefly described, a number of views of the most important scientific buildings throughout the country, including the new building proposed for the Franklin Institute, in which it was hoped that the various technical societies of the city would find quarters.

Mr. John C. Trautwine, Jr., exhibited a large section view of the Bouzey Dam and described the probable causes and results of its failure. He stated that as the center of the dam seemed to have slid away bodily, this was probably a case in which a dam with curved line would have been stronger.

Regular Meeting, June 1, 1895.—President George S. Webster in the chair. Forty-one members and visitors present.

The Special Committee appointed to co-operate with the Committee on Standard Gauges of the American Society of Mechanical Engineers, reported the communication sent to the latter as the result of their labors. The committee favored the adoption of the proposed decimal gauge in which all small measurements are expressed in thousandths of an inch, but feared that an international system which should unify the two standard now in use—the inch and the meter—would not be practicable at

present. It recommended that the work of the American Society's Committee be continued, to ascertain if international unity of method in measurements is possible. The Committee also suggested that the use of the word "mil" be encouraged for expressing the thousandth part of an inch.

Mr. George H. Paine presented a paper on "Certain Interesting Features in the Manual Interlocking of Railroads," illustrated by large charts. The paper was discussed orally by Prof. L. F. Rondinella, Dr. Henry Leffmann, and Mr. George S. Webster. Mr. Emile Geyelin (non-member) read a paper on "The First Pair of Horizontal Turbines Working on a Common Axis," afterwards discussed orally by Messrs. J. C. Trautwine, Jr., A. Falkenau and John Birkinbine.

Mr. Birkinbine announced that he had visited Atlanta, Ga., recently, to inspect the preparations for the exhibition to be held there, opening September next, and had found that it was laid out upon a scale which had been exceeded in this country probably only by our Centennial Exhibition and the World's Fair at Chicago.

Regular Meeting, June 15, 1895.—President George S. Webster in the chair. Seventy-four members and visitors present.

The Chairman of the Information Committee reported that there would be no excursion of members until the fall. At that time it was hoped to plan a visit to electrical engineering works in connection with the course of practical talks on electricity to be delivered at the Club at that season.

The President again called attention to the fact that the members of the House and Membership Committees wear badges that they may be distinguished, in order to introduce new members and otherwise promote social intercourse at Club meetings.

Mr. William D. Beatty read a paper on "The Philadelphia and Reading Coal Storage Plants," which was discussed orally by Messrs. A. Falkenau, C. W. Hunt, J. M. Dodge, E. F. Davis and Charles Piez.

Upon motion, a unanimous vote of thanks was extended to visiting speakers for the information with which they had favored the Club.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, April 20, 1895.—Present: President George S. Webster, Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Edward K. Landis, William J. Hoyt, Charles L. Prince, W. C. Furber, Henry Leffmann, Edgar Marburg, and the Secretary.

The President reported that he had signed an agreement with J. C. Baker, to act as advertising solicitor for the Club's PROCEEDINGS, in accordance with statement made to the Board at the last regular meeting.

The Treasurer's Report showed:

Balance from February	$1,039 80	
Amount received during March	548 60	
		$1,588 40
Amount expended during March		304 65
Balance March 31, 1895		$1,283 75

The Finance Committee reported that all bills up to April 1st had been approved and paid.

The Secretary reported that he had this day received from the Chairman of the Finance Committee the Treasurer's bond, and would deposit it in his personal custody in the Girard Trust Company, as directed.

Upon motion, at his suggestion, the Secretary was authorized to have new forms of notification of election to membership printed, including a statement of initiation fees, dues and other indebtedness, and instructions to the member-elect to introduce himself on his first visit to the Club House. In this connection it was also resolved that the President should introduce such new members to the Club at its meetings.

Upon motion, the Membership and House Committees were authorized to provide themselves with badges by which they could be known to members attending Club Meetings.

The House Committee reported that in accordance with arrangements made with the Girard Estate, work had been going on during the past two weeks at the Club House. Most of the walls had been scraped, the meeting room repapered, parlor and library papered, the old carpets that would be used would be cleaned and relaid, while new carpets had been selected for the first floor rooms and halls and stairs. More coat and hat hooks had been provided, a new bath tub put in, the chandeliers in the meeting room had been made to be turned off from the valve in the hall, and before the next regular meeting of the Club, all of the improvements would probably be made. The Committee also stated that $350 would probably cover the cost of the improvements to be paid for by the Club.

The Information Committee reported that arrangements had been made to give four talks on the principles of practical electricity in the early fall, and at the Committees's suggestion that they be given on the evenings of the Saturdays between Club meetings, they were ordered to make arrangements accordingly.

REGULAR MEETING, May 18, 1895.—Present: Vice-President John L. Gill, Jr., Directors Henry Leffmann, William J. Hoyt, and the Secretary.

As there was no quorum, at 5.15 P.M. these members adjourned.

Regular Meeting, June 15, 1895.—Present: President George S. Webster, Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Edward K. Landis, Chas. L. Prince, Edgar Marburg, Henry Leffmann, William J. Hoyt, and the Secretary.

The Treasurer's Reports for April and May showed:

Balance from March	$1,283 75
Amount received in April	521 10
	$1,804 85
Amount expended in April	489 16
Balance April 30th	1,315 69
Amount received in May	436 50
	$1,752 19
Amount expended in May	323 44
Balance May 31st	$1,428 75

The Membership Committee reported two applications received.

The Publication Committee reported that Mr. J. C. Baker, with whom an agreement had been made to act as advertising solicitor for the Club's Proceedings, had been quite unsuccessful, and had cancelled the agreement. Upon motion, the Chairman of the Committee was instructed to confer with Mr. Annear, regarding his acting as advertising agent for the Proceedings.

The Library Committee requested an appropriation of $100 to be used in making necessary improvements in the library during the summer months. After considerable discussion, it was thought that a larger amount could be well used in this work, and $150 was appropriated to the use of the Committee.

The House Committee reported that the improvements in the Club House were about completed, and that the Committee would soon send out a circular to suitable parties requesting information and description of any appropriate framed pictures that they might be willing to present to the Club, after which the Committee could make selections and request those thought most desirable. Upon motion, the Committee was authorized to dispose of old pictures that were of no further use to the Club.

CONTRIBUTIONS TO THE LIBRARY.

From March 15, to June 15, 1895.

From American Iron & Steel Association.

Statistics of the American and Foreign Iron Trades for 1894.

From American Water Works Association.

Proceedings of the Fourteenth Annual Meeting held at Minneapolis, 1894.

From Bureau of Education, Washington, D. C.

Report of the Commissioner of Education, 1891-92.

From Chief of Engineers, U. S. A.

Annual Report, 1894.

From Coast & Geodetic Survey, Washington, D. C.

Legal Units of Electrical Measure in the United States.
The Constant of Aberration.
The Direction and Intensity of the Earth's Magnetic Force.

From Engineering Society, University of Illinois.

Technograph, No. 9.

From Rudolph Hering.

Report on the Drainage of the City of New Orleans, 1895.

From Institution of Civil Engineers, London.

Abstracts of Papers in Foreign Transactions and Periodicals.
Androssan Harbour Extensions—Robertson.
Boiler Explosions—Fowler.
Colliery Surface Works—Wain.
Construction of Tilbury Docks—Scott.
Dredging in the Lower Danube—Kuhl.
Estuary of the Tay—Cunningham.
Filtration of the Müggel Lake Water Supply—Gill.
Fitzroy Suspension Bridge—Brady.
Heat Losses to the Cylinder Walls of a Steam Engine—Barraclough.
Long Distance Levelling—Bagnall.
Machinery for Sea Works—Kenny.
Machinery of Warships—Durston.
Mountain Railways—Berg, Collett & Pownall.
Otago Harbour Improvement Works—Barr.
Pecos Viaduct, Texas, U. S. A.—Hodge.
Railway Construction in the Philippine Islands—Liddle.

Steam Tramways in Italy—Amoretti.
Tansa Flood Discharge—Clerke.
Timbering in the Ampthill Second Tunnel—Matheson.
Wallsend Graving Docks—Thompson.

From Interstate Commerce Commisison.

Eighth Annual Report, December 1, 1894.

From A. Rosewater.

Annual Report of the City Engineer of Omaha, December 31, 1894.

From William Sellers & Co.

Machine Tools.

From State Board of Health of Massachusetts.

Report upon Metropolitan Water Supply, February, 1895.

From State Geologist, New Jersey.

Report on Water Supply, 1894.

From Wagner Free Institute of Science.

Transactions Volume 3, Part II, March 1895.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit is given the PROCEEDINGS.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XII.] OCTOBER, 1895. [No. 3.

XIV.

SUBMERGED PIPE LINE FOR THE PENNSYLVANIA SANITARY SEWERAGE COMPANY, AT READING, PENNA.

By WILLIAM H. DECHANT, Active Member of the Club.

Read October 5, 1895.

As a matter of introduction, I wish to say, that the City of Reading is securing a house sewerage system which is being installed by the Pennsylvania Sanitary Sewerage Company, of Philadelphia, under the charge of Mr. J. J. Deery, their General Manager, and under Mr. Edwin Chamberlain, City Engineer.

The sewage is conveyed by sewers to a pump house on the east or city side of the river, where it is screened, the solid matter removed and burned and the sewage water remaining pumped across to the west side of the river and down along the river to a disposal plant about one mile from the city. At the disposal plant, the sewage water undergoes a process of sand filtration, the effluent finally reaching the river. The pipe lines are intended to eventually carry 15,000,000 gallons per twenty-four hours. At the site of the river crossing to which this paper relates, the width under water along the pipe line is about 400 feet, and the deepest part about 10 feet below extreme low water, the average

depth being about 8 feet. For the river crossing a 30-inch cast iron pipe was adopted weighing a little more than two net tons per length of 12 feet. It was at first thought necessary to make the joints of the bolted flange pattern.

Several plans were suggested for submerging this pipe line. The writer proposed the plan here described, afterwards contracting to execute the work for a lump sum, which came within the previous estimates. One of the principal items of saving, amounting to about a thousand dollars, was effected through the use of a bell and spigot instead of a flanged pipe, made possible by this plan.

The contract was entered upon on the 17th of April with the least possible delay, in order to complete the work before the time for the expected spring freshets, which, as is usual in such river work, was one of the dreaded contingencies that had to be reckoned with. Last year during the month of May, the river at this point was subjected to a ten-foot flood. Had the work been overtaken by such a flood, or even a very much smaller one, the result may well be imagined.

The old watchword along the canal, "Never trust the Schuylkill over night," had to be violated, but we concluded that this watchword had originated long before the existence of our present Government Weather Bureau, and that by the help of the latter we could at any time determine the probable weather for three days in advance, or at least be warned against any dangerous changes and manage the work accordingly.

The first operation was the excavation of a channel or bed across the river for the reception of the pipe, so as to place the bottom of the latter about 2 feet below the ordinary river bottom. At the banks, this excavation amounted to a depth of from 3 to 5 feet. To make this excavation, a dredging machine was secured from the canal department of the Philadelphia and Reading Railroad Company. As this machine had first to be employed in opening the channels on the canal for the season, its use for the purpose mentioned could not be obtained until the 20th of May, on which date the work in the river was begun.

The dredging of the channel required six days. The bottom of the river had been previously sounded with a pointed steel rod,

driven down to ascertain the location of bed rock. This sounding showed the rock deep enough to allow the proper depth for the trench which was afterwards confirmed by the dredging, although the bed rock was scraped at several points. The material found in the bottom of the river, except at the embankment, consisted of small boulders and gravel, very hard to dredge. The east shore was covered by a deposit of black mud; the west shore was a compact bank of clay, mixed with boulders and full of roots and stumps.

Before the dredging was begun, a line made of No. 8 wire, with marks fixed at distances apart of 12 feet 1¾ inches, was stretched across the river, 10 feet north of the center line, so as to keep the dredging machine exactly on line.

The proper depth below the surface at each pipe joint was marked on a tag attached to the wire line. The distances of 12 feet 1¾ inches represented the average length of pipes between joints, which had been previously determined by measurement.

The plan used for submerging the pipe line is briefly as follows:—The whole line of pipe was first suspended from a trestle work, the pipes being jointed and held in the exact relative positions they were to occupy in the bottom of the river. A long screw rod was attached to each pipe. All the rods were lowered uniformly by placing a man at each screw and by keeping time in the lowering.

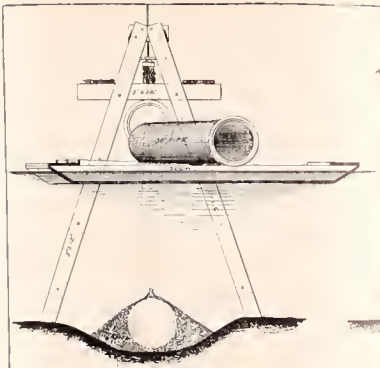
Prior to the commencement of the work in the river, the thirty-three trestles and the double chord to connect them had been framed and piled on the shore. The trestles and chord were made of double 3″ x 12″ hemlock plank, held apart by 2 and 3 inch fillers and bolted together with screw bolts. Two small scows of hemlock plank, 10 feet wide, 24 feet long and 14 inches high, had also been constructed for use in setting the trestles and for carrying the pipe from the shore to the trestle work. The one for setting the trestles was rigged with a simple pair of shear legs and brace placed on the bow, to the top of which a pair of blocks with a hand line were fastened. This scow was also provided with two 1½ inch round iron spuds, 14 feet long, so that it could be anchored and held in place in any position in the river.

After a trestle had been erected and properly secured, the position for the next one was measured off on the scow and 1 inch square pointed bars of iron were driven into the bottom of the river at the points where the feet were to rest. The depths at these points were then carefully determined and the bottom prepared as well as practicable. The trestle legs were sawed off to suit the depths and the trestle floated from shore to the erecting scow, which had been moved back in the meantime so as to be in position for setting the trestle. The trestle was raised by the blocks and hand line and set in position, being guided in its descent by the bars which had been driven to mark the place for its feet. After it was properly adjusted, the four lines of run plank were thrown ahead from the last trestle and fastened with bolts. The run planks and center chord were formed of planks, 24 feet long, placed so as to break joints, thus binding the longitudinal construction together and making it continuous, as shown in the accompanying illustration. It was thought that it might be necessary to weight the trestles in order to sink them, but the weight of the four lines of run planks proved sufficient for this purpose.

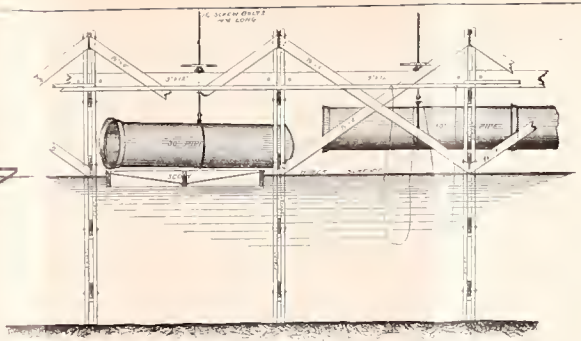
The erection of the trestles required three days. After the erection of the whole line and before the chord was placed, any inequality in the vertical alignment was corrected by raising or lowering the cross piece or cap supporting the run and chord. The design of the trestle made this adjustment very simple.

After the chord was placed along the trestles, the work of suspending the pipe was begun. The pipes had been unloaded from the cars on the west shore of the river. A skidway had been constructed from the top of the embankment to the river, so that the pipe could be snubbed from the shore on to the small scow. This scow had been constructed so as to carry the pipe balanced on a trunion in its center. The pipe could thus be easily slewed around to almost any position for entering it under the line of trestles. The trunion was made so that it could be turned by a lever, which enabled the operator to also move the pipe some distance endwise.

While the scow was moved from the shore to the trestle work, which was but a short distance, the suspender band was placed



END ELEVATION



SIDE ELEVATION

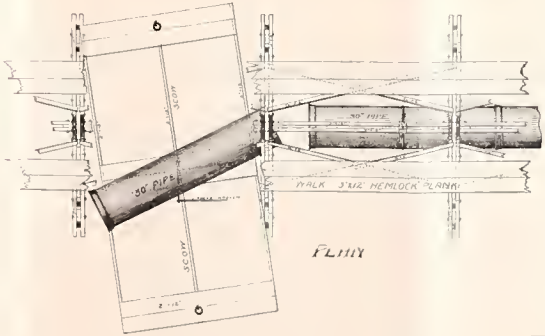
PLAN

USED IN

SUSPENDING PIPE LINE

IN POSITION FOR SINKING

SCALE - 1/8" = 1'



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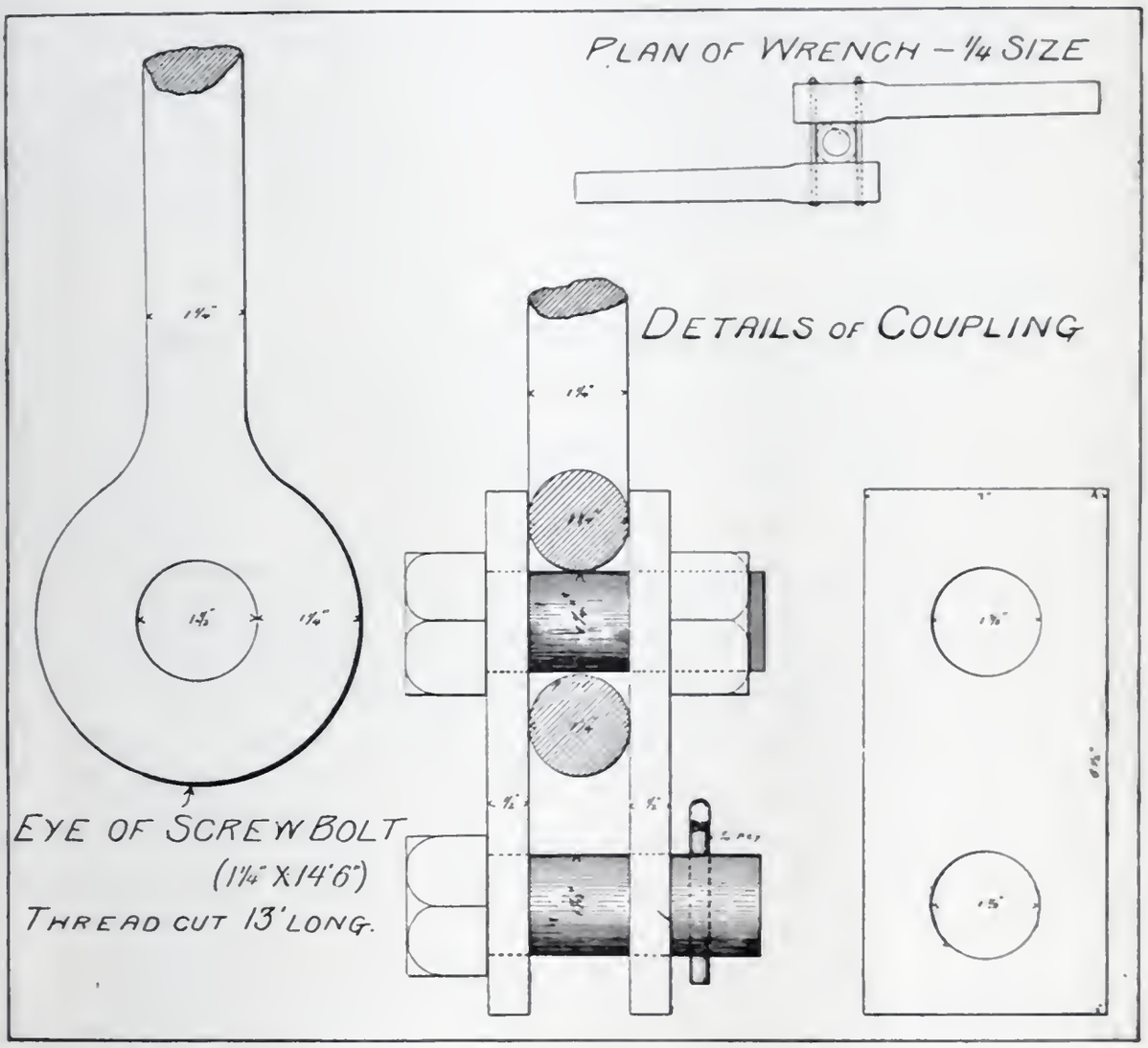
around it. This consisted of four separate bands, of five strands each, of old No. 8 telegraph wire, which had been previously prepared ready to slip over the pipe.

Arriving at the trestle work, the scow was run underneath so as to bring the center of the pipe immediately below the screw rod provided for its support. The rod was lowered so that the coup-



ling could be attached to the suspender band; the rod was then raised, lifting the pipe, and the scow thus relieved was ready to repeat the operation. A gang of men on the trestle work raised the pipes to their proper positions and moved them endwise so as to properly enter them. This endwise movement was accomplished as follows:—The center chord upon which the pipe hung, was made by two 3″ x 12″ pieces bolted together with a space of two inches between, 2-inch fillers being placed at the joints on the trestles. The 1¼-inch screw rod passed through this

two inch space and through a cross plank, supporting a cast iron washer upon which the nut rested. A simple lifting jack, placed on the chord and operating against this cross plank, moved it and its load in either direction along the line of the chord.

After the whole line of pipes had been raised and properly entered and adjusted, which could be done perfectly as the pipe could be examined inside as well as outside, the lead joints were made. From the convenience of the trestle work and scows and from the fact that the pipes hung clear all around, this part of the work was accomplished with less trouble than would have been experienced in a trench on land. Rings of asbestos packing were clamped around the joints to hold the lead while the joints were being filled.

During the last day, the whole trench across the bottom of the river was again carefully examined to see that it was entirely clear of obstructions. It was found that soft mud from the sides of the cut on the east shore had settled into the trench to the depth of between 1 and 2 feet and for a distance of about 24 feet. This had to be removed by rigging up a hand scoop.

Wires were also placed to release the coupling between the screw rod and suspender band, from the suspender band, so that after the sinking was completed, everything could be removed except the wire suspender band around the pipe. A No. 8 wire was attached to the coupling pin and a No. 12 wire to the small key in the coupling pin. The pipe line was also securely closed at the ends.

After these adjustments had been completed the lowering of the line received attention. The work in the river thus far had taken seven days—three days for the erection of the trestles and four for hanging the pipe, adjusting and making joints. On Saturday, the 1st of June, at 4 P.M., the lowering was begun.

In the manipulation of the screw rods it was found that one man was not able to handle a wrench singly owing to the power required, so that two men had to be provided for each screw, this required about seventy men, counting the foremen. An assistant was placed about midway of the line provided with a shrill whistle and the men were carefully instructed to make one complete revolution with their wrenches every time the whistle

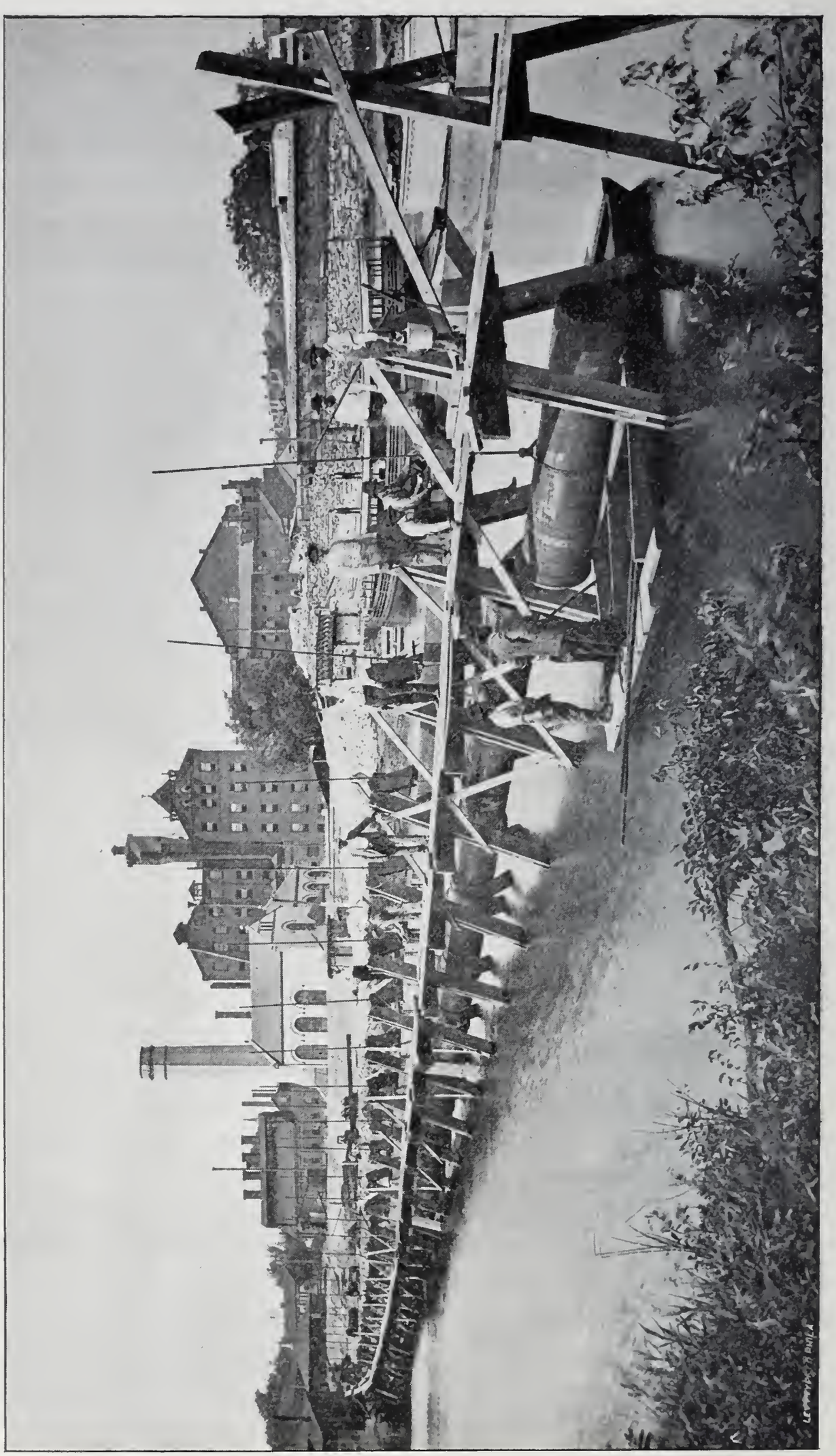
sounded. The men upon whom we could depend were distributed among the green hands and foremen and assistants were placed at short intervals to see that all performed their duties carefully. The fastest time made during the lowering was one revolution of the wrenches every five seconds.

During the sinking an unexpected hitch occurred and one that I could not immediately account for. I had made calculations to determine whether the pipe would float when filled with air, while being sunk. In these calculations I had counted the cylinder of air as being 30 inches in diameter and 12 feet long and had found that the pipe would sink when filled with air. To my surprise, however, when the pipe line was lowered into the water, it floated and it was necessary to stop the lowering and with buckets and hand pumps to add water ballast, which was done from the east end. The reason for this miscalculation became clear at second thought, namely, that I had failed to consider the thickness of the shell of the pipe in estimating the displacement.

The lowering of the pipe was continued until about eight o'clock, when it began to get too dark to properly watch the men and was therefore discontinued until Monday morning. The pipe was within one foot of its proper depth, and on Monday morning the lowering was successfully finished in less than one hour.

The pipe line, when at its proper depth, did not touch the bottom by an average clearance of about 6 inches. This provision was made in order that there might be no strain on the joints or any part of the pipe from irregularities along the bottom. After the pipe had reached its proper depth, it remained suspended until gravel and cinder filling was placed at each joint so as to provide a uniform bearing. The screw rods were finally released on Monday afternoon.

When the submerged pipe was in position, the end connections were made by throwing earth-puddled coffer-dams, carefully made, over the ends at the shores. The coffer-dams were so well constructed, that an ordinary tin pump kept out the leakage, and the work in the last of the two coffer-dams showed the pipe to be water-tight. A quantity of water was bailed out of the pipe in



the morning, and in the afternoon when the lead joint was made, the water in the pipe had not risen perceptibly.

The work of releasing and removing the iron screw rods and couplings by use of the wires attached to the keys and pins was accomplished without any trouble. The trestles, etc., were floated to shore and taken apart, and the material, being of a convenient and marketable size, and being practically uninjured, has almost all been disposed of at more than 60 per cent. of its cost.

DISCUSSION.

Mr. John Birkinbine.—The plan described is ingenious and has the merit that it can be carried out with promptness after the arrangements have been perfected. For the purpose for which the pipe is to be used, and for the distance covered, the plan may be very satisfactory. There, however, appears to me to be a possibility of defects in the joints, when water is supplied under pressure, and when such water does not carry material which would have a tendency to fill any openings in the joints. The possibility which Mr. Dechant credits to such joints, viz., to "give a little," may mean that each joint may "leak a little," and a leak between iron and lead is apt to increase rather than decrease. Some method of holding the pipes firmly together would seem to be advisable.

For laying submerged pipe, special joints have been patented. In one of these the spigot end, made nearly spherical, moved in a lead socket cast into the bell of the pipe. In another, the inside of the bell was turned to approximately a spherical shape, and a bell of lead was cast on the spigot end after it had been inserted in the bell, being held in place by cast projections. In a third, rings of lead were placed in the bell of the pipe, and a tapered spigot forced these into a joint. A line of 36-inch pipe was laid across the Schuylkill River at Columbia bridge, using the joint first described and proved defective. I presume because some of the lead joints were compressed unequally, leaving openings which were worn larger by the water escaping through them.

A plan which I used several times, in one case crossing the Susquehanna River where it is half a mile wide with a 16-inch

pipe, is as follows: The pipes were ordinary bell and spigot pipes with lead joints, supplemented by wroughtiron stirrups shrunk upon lugs cast on the pipe. When eight pipes had been connected, an iron ball and socket joint was inserted, then eight more pipes were connected, the whole work being done on trestling similar in general design to that described. When two sections of 100 feet each had been connected, the pipes were simultaneously lifted by a series of tripods with differential pulley blocks, and the first 100-foot section was lowered to the trench, the second section remaining in an inclined position, suspended from the tripods, until another section was ready to be handled. In this way the river was crossed, and a large part of it was kept open for the passage of rafts, etc.

The stirrups kept the various sections rigid, and as the ball and socket joints were made of iron and neatly fitted, the tendency was for the ball and socket to rust tight after being in place. This pipe gave entire satisfaction, but two small leaks being indicated and located by the hissing noise readily heard when pressure was applied. These were remedied by inserting bran in the line of pipe, and subsequently by removing the pressure for a few days. When finished the iron surfaces of the ball rusted together. I question whether, in pipes 12 inches or more in diameter, a flexible joint of lead against iron is advisable, and in the plan described by Mr. Dechant there appears to be considerable risk of having defective joints unless the pipes are held together by some stiffening medium.

Mr. A. J. Fuller.—In 1885 a section of a 36-inch supply main was laid in West Philadelphia, the trench being refilled at both ends of the line in the usual manner, but leaving an unfilled space about 300 feet long in the center. This space was reserved for the purpose of ascertaining, by experiment, the cost of the class of work known as refilling and puddling of trenches.

I left the work, temporarily, and on my return I found that the trench had been about one-third refilled with earth and the water for puddling had been run into it within one or two feet from the top of the trench—the variation above the surface of the water being due to the grade of the street. The puddling feature had been over-done, for the displacement of water equal to the area of the

cross-section of a pipe of this size exceeds its weight by 109 pounds for each lineal foot, and the resulting buoyancy caused the pipe to rise or float in such manner that at the point equidistant from the ends of the unfilled trench, the top of the pipe was even with the top of the trench, and curved in both directions from this central point to where the trench had been previously refilled, thus forming—as appeared to the eye—a perfect arch. Every lead joint was drawn, more or less, from the bells, beginning with a slight movement at the ends of the open trench and gradually increasing to a maximum of about $\frac{3}{8}$ of an inch at the center of the line. The movement of the lead was outward, and was greatest on top of the pipes and the reverse on the bottom.

The trench was afterwards drained off, and the back filling that had settled under the main was removed. The pipe was then lowered to its proper place, and this action drew most of the joints (lead) to their original positions, and they were then recaulked.

Previous to this experience, no thought was given to the matter as to whether a pipe would float under certain conditions or whether any action resulting from buoyancy would affect the lead joints; but great care has since been taken to guard against danger from this source when we are laying mains from 20 to 48 inches in diameter, all of which, with a buoyancy inversely in proportion to the weights for each class of the nominal sizes, will float.

We put to practical test, when removing a 36-inch cast iron standpipe from the Fairhill Reservoir, our experience gained in the case quoted above. The standpipe in question was at the end of a pumping main and extended from the bottom of the reservoir to a few feet above the water surface. The object of its removal was to change a pumping main to a supply main, and it was desirable to cut the standpipe off as near as possible to the bottom of the basin. The reservoir could not be emptied for this purpose, and the work of cutting the pipe was accomplished in the following manner:

The water in the reservoir was first drawn down to a depth of ten feet. Two wooden plugs were then placed within the standpipe, one just above the 10-foot water line and the other at

the mouth of the pipe, both being made water-tight by means of lead joints. The pipe was then cut from the outside at the water line, or just below the position of the lower wooden plug—the workmen standing on a float to do the work. After cutting the pipe, the loose portion, with the water-tight ends, was pulled over by means of a line attached to its upper end. The pipe fell into the water almost horizontally and sank below the surface, but it soon appeared again and floated like a cork, with rather more than one-fourth of its bulk projecting above the water, and with one end a little deeper than the other, owing to the additional weight of a bell on that end.

The pipe was pulled ashore by means of the line and was then "tarbuckled" up the slope to the top of the reservoir embankment.

The whole operation was inexpensive and was performed in a few hours, the only materials used being the two wooden plugs, a few planks, with which the float was made, a rope and the usual caulking tools.

XV.

TOPICAL DISCUSSION—DURABILITY OF IRON IN MODERN BUILDING CONSTRUCTION.

October 19, 1895.

Mr. W. C. Furber.—The durability of iron in modern building construction is a subject of importance, but has so far received little attention at the hands of constructing engineers and architects. In buildings, owing to the impossibility of renewing the protective covering of the metal work, or even examining its condition, the question of its preservation is a serious one, which cannot be lightly dismissed by the conscientious constructor. In high buildings, which have become the order of the day, owing to their utility and economy, the decay of the main lines of support through corrosion, would involve problems of responsibility and cost, which all those in any way connected with their design and erection would do well to thoughtfully consider. As the possibility of renewal of many of the parts of such buildings would be practically or commercially out of the question, our attention must be turned to the preservation of the original structure, and as iron will rust under certain conditions, we must endeavor to prevent those conditions or insulate the iron from them, in case their prevention is impossible. This then leads us directly to the question of protective coverings. It is needless to say that many coverings have been tried and found wanting, and it is the purpose of this discussion to open the way toward suggesting better methods than those in general use.

The process to be pursued in preventing corrosion may be said to consist of two parts; first, the cleaning of the metal by means of pickling or otherwise, in order to remove all dirt, mill-scale, particles of imbedded slag, and to expose the actual body of the metal, so that the covering may be put on in direct contact with it; second, the application of the protective covering. The character of the latter will vary with the use to which the

material is to be put, and with the degree of exposure and importance of the member covered. For instance, column footings, column bases, metal work exposed in boiler rooms, double, triple and quadruple webbed plate girders, columns imbedded in moist masonry walls, iron stacks exposed to the action of the gases of combustion, will require different treatment from interior floor beams, which are usually protected from dampness.

The presence of mill-scale and imbedded slag, always found in finished material as it leaves the rolls, is regarded as a fruitful cause of rust, and its removal by pickling in weak sulphuric acid before shipment and use is considered desirable by most investigators. I hope that this phase of the subject, its feasibility and commercial aspect, will be discussed by those conversant with the practice of the rolling mills. I may say, that since it is considered necessary to pickle the plates forming the hulls of vessels, which can be in a degree examined, it would seem even more important to employ such a process in treating the metal to be used in those parts of a building which can never receive examination after erection.

The selection of the covering will have some influence in determining the form of the columns to be used. For the best coverings known to-day, an open-section column has many advantages. Closed sections permit the accumulation of water, dirt, grease and drill cuttings, which cannot be removed after erection, and are potent factors in starting rust.

The coverings available at present are paints, bituminous coatings and cement, all of which may probably be used on the same structure to advantage. Portland cement properly applied has many advantages over other coverings, and may be said to be the most efficient on account of its permanence and because the thoroughness of its application is readily ensured. Heretofore it has been used only on such parts of a structure as are below ground, though there seems to be no good reason for not using it to cover other parts of the metal work as well. The application of the most effective covering must be accompanied, however, by the most conscientious inspection, or it may result in failure to accomplish the desired result. Specifications, however carefully prepared, are alone not sufficient.

From direct experimentation on rust prevention, I have been able to add but little to the existing knowledge on the subject, and shall, therefore, have to content myself chiefly with abstracting and summarizing some of the more important results found by those who have given more time to its study. I have looked up the literature on the subject of rustless coatings for iron and steel, which seems to be the only method known at present for preventing corrosion. If you will bear with me, I will review this briefly and place the conclusions of those who have gone more deeply into the subject at your disposal, as a basis for further discussion.

In Ledebur's Handbook, pages 277 to 281, can be found an essay upon "The Oxidation of Iron and its Admixtures; Rusting and the Influence of Liquids upon Iron," in which Prof. Ledebur states that the name of rust is in a general way conferred upon every basic salt of iron which is insoluble in water and which has been produced by the influence of any liquid upon the iron. Specifically, it is applied, however, to the hydrated oxide. He instances Pliny's reference to the curse of rust laid upon the iron as a retribution for the many evil deeds to which it lends itself in the hands of robbers and murderers.

He shows that, since rust is chiefly hydrated oxide of iron, its formation cannot occur in perfectly dry air, and, furthermore, that it contains small quantities of carbonic acid, proving that the acid is partly instrumental in the formation of rust, which fact is illustrated by exposing two pieces of iron, one to ordinary water containing carbonic acid, and the other free from it. The former will soon be covered with rust, and the latter will remain unaffected a long time, if the atmosphere is excluded, which always contains carbonic acid. Owing to this fact, quicklime or other alkali is sometimes added to water to prevent rusting.

He also shows that the combined action of three bodies is required to produce rust, viz., water, free oxygen, and an acid, which substances, however, are present in the atmosphere. Rusting cannot occur where one of these substances is lacking.

The difference in the composition of the metal is also shown to affect its resistance to corrosion. The galvanic effect produced by imbedded slag is also referred to. The protective effect of

zinc in boilers is noted as preventing corrosion, as is shown by the zinc becoming the electro-positive pole. The tendency of iron to rust is increased when in contact with metals which are electro-negative, as copper, tin, lead, etc.

I wish to call attention especially to the valuable investigations of Mr. M. P. Wood, who, in December, 1894, read a paper (*Proc. Am. Soc. M. E.*, No. 626, Vol. XVI) on "Rustless Coating for Iron and Steel," from a review of which the following points are abstracted. In this paper specific reference is made to the action of mill-scale on iron, and the remarks of Sir Nathan Barnaby, Mr. Rialton Dixon and Mr. Farquharson are cited, showing that no pitting of the metal occurred when exposed to water, where the metal was free from mill-scale, and that the action of mill-scale was equal in corrosive effect to a similar quantity of copper.

He also refers to Mr. Ward's paper (No. 598, *Proc. Am. Soc. M. E.*, 1894) upon the same subject, which confirms the conclusions of the various naval authorities in the stand they have taken upon the removal of the mill-scale from all plates used in the construction of vessels for the navy. Reference is also made to the property of setting possessed by red lead, and, further, to its power of oxidizing, to a slight extent, the surface of the metal to which it is applied, forming a black magnetic oxide which he regards as a valuable property, as this oxide is electro-positive to the metal covered. The internal corrosion of ships is referred to, and the best protective coverings are discussed, viz., cements, bituminous coatings and paints.

The methods of painting in vogue are unfavorably criticised, and the practice of painting over mill-scale, grease and dirt is condemned. Clean, bright metal surfaces to receive paint are advocated, and the painting of bolts and rivets before rusting is recommended. The use of benzine and bisulphide of carbon as thinners is condemned. The painting of the Forth Bridge is severely criticised, and the method in use there declared to be a mistake. Criticism is also made of the painting of various other important bridges in which the paint does not prevent corrosion, owing to the lack of proper preliminary methods of cleaning before painting, etc.

The same writer, in a paper read at the Detroit meeting of the

American Society of Mechanical Engineers, June, 1895, upon the same subject, defines paint, states what it should consist of, discusses the destructive action of gases upon it, the chemical action which sometimes takes place between the paint and the body covered, and the formation of magnetic oxide. He also refers to asphalt coverings, their desirability and efficiency; also to the evil effects of iron oxide paint on various important structures. Mr. Wood, in this paper, also reviews a paper by Mr. Emile Gerber (*Proc. Am. Soc. C. E.*), on iron oxide paints, and states that he thinks that Mr. Gerber arrived at certain erroneous conclusions, overestimating the value of iron oxide paints.

Reference is further made to the formation of magnetic oxides. The resistance of carbon paints, graphite, asphalt, etc., to acids and alkalis is favorably commented on, and instances of their superior qualities to lead paints are given. Reference is made to a paper by Mr. Walter G. Berg (*Eng. News*, June 6, 1895, p. 370), on the literature of anti-corrosive compounds, also to the remarks of Philip Hichborn, Chief Constructor U. S. N., on the efficiency and desirability of cement protective coatings for the hull plates of ships. This completes the list of my references.

I have here some samples of iron for which I am indebted to the Tacony Iron and Metal Works. There are four samples, two from which the mill-scale has been removed, one of which is painted, and two showing the metal as it comes from the rolls, of which one is also painted. The pickled samples show plainly how well the paint adheres to the clean surfaces. The scale is very easily seen upon the other samples.

Mr. C. D. Rinald.—I think that a great deal has been said about paint, without reference having been made to the first and chief consideration which should govern the manufacture of a rust-preventing material. The first thing to do is to find out exactly what rust is and how it is caused, as without this knowledge all efforts to protect iron are more or less like groping in the dark. Mr. Furber has given us Prof. Ledebur's explanation. His statement is of course quite correct. I am sure that I would not want to contradict such an authority. But I think that I can give a plain explanation of the process of rusting, its cause and its prevention, in a more practical and less scientific manner. Rusting is caused

by the combination of oxygen with iron, but this combination cannot take place before the iron has been prepared for it by an acid. Now the acid which generally does this preparatory work is carbonic acid, but it may just as well be some other acid (sulphuric for instance), or it may even be an alkali. Knowing this much, we see readily that one of the duties of a protective coating ought to be to prevent carbonic acid (or other acids or alkalis) from penetrating to the iron, which then cannot combine with oxygen. I might add here that it is easier to protect clean iron than iron which has already started to rust. This is due to the fact that rust is of a hygroscopic nature; that is to say, it attracts water and even water vapors that are anywhere near the iron. You can verify this by placing in the same room alongside of each other a piece of clean iron and a piece of rusty iron, when you will find that the clean iron will remain free from rust, while the other, even if only slightly rusted, will continue to rust, because the rust upon it will attract all the moisture it can possibly get from the atmosphere and transform it into water. The process of rusting may be traced as follows:—All the water, as well as dew and mist, in populated districts contains carbonic acid to some extent. This acid, even when deposited in very small quantities upon the iron, will at once dissolve some of the latter and form a soluble ferrous carbonate therewith. The chemical action thus started continues rapidly, the processes which I shall now describe, intermingling and helping each other. The ferrous carbonate turns into ferrous bi-carbonate, when hydrogen is liberated, but is not allowed to pass off, because it at once combines with oxygen, forming water. This oxygen may be drawn from the air or from nearer sources, for instance oxide paints. But the hydrogen has no greater affinity for oxygen than the ferrous bi-carbonate, which will also draw on all available sources for oyygen, and will then rapidly change into ferrous hydrate, on which occasion carbonic acid is set free. Here then we have the original carbonic acid which after having done its duty in forming ferric hydrate has become free again to dissolve more iron, and now not even liquid water is required to enable the rusting to continue, because the rust thus formed will draw on the atmosphere for moisture, transforming it into water in the manner already described.

After thus considering the origin of rust, let us see what protection against it is offered by paints. Being thoroughly familiar with this subject, I feel warranted in saying that in most paints for iron, cheapness seems to be the chief consideration. It is evident, of course, that a paint that will not protect the iron will prove a very expensive one in the end, no matter how small its first cost may have been.

Before I go any further, I want to say something about that skin of black or magnetic oxide, which, according to what Mr. Furber has read to you, has been found under red lead paint. This black oxide is simply rust, containing, however, a relatively smaller proportion of oxygen than the red rust. The red rust consists of two parts (atoms) of iron and three parts of oxygen, while the black rust consists of three parts of iron and four parts of oxygen. This black rust has the same quality as the rust of other metals, that is to say, it will give the iron a perfect protection. To my knowledge it is used exclusively, however, for small articles and not for iron exposed to the weather, the reason being, that black oxide, while very hard, is also extremely brittle, and therefore a small piece of it is easily broken or cracked off. As soon as this takes place, the whole coating of black rust immediately turns into a rust-producer rather than a rust-preventer, because the black oxide is electro-negative and the exposed iron electro-positive. Thus galvanic action of great force takes place and the black oxide is thrown off in a short time by the red oxide. This can be observed frequently on iron signs which have been treated by that method. I wish to say that I have never found black oxide under red lead on bridges, train-sheds or like structures, and I think that I may safely claim that nobody else has ever found it on a structure over ground. I first found it mentioned by Mr. Thompson before the Society of Engineers at Manchester, England. If my memory serves me right, he said that he found it under the red lead on the hull of a vessel, or at least on some iron that had been exposed to the action of sea water. I believe that this action and not the red lead caused the formation of the skin, because, as we all know, red lead contains a great deal of oxygen, and would therefore be favorable to the formation of red rust rather than black rust, the latter, as I have before stated, contain-

ing more iron and less oxygen than the former. I therefore believe that it would be quite impossible for a skin of black or magnetic oxide to form under a red lead coating on iron which is exposed simply to atmospheric influences.

Considering all the points just touched upon, it seems to me that in making a protective paint, it would be a good idea to use such pigments only as do not contain any oxide at all, and which are not affected by acids or alkalis of such strength as those they will be brought in contact with by the atmosphere or which will be deposited on them by dew, mist, or rain. These principles have been carried out in the manufacture of what is known as "Bessemer" paint.

Now as to the liquid for mixing a paint, linseed oil is generally considered as the best material for that purpose. I take exception to this. Linseed oil can be made into an excellent liquid for the purpose, but it has to be subjected to a special treatment. In its natural state it is porous and frequently even becomes hygroscopic. It is also easily affected by weak acids and alkalis. It is well-known that red lead alone is sufficient to decompose it and to form a lead soap with it. In the first place it should be treated in such a manner that it will no longer contain water, and then its porousness and its affinity for acids must be counteracted. By carrying out all these details, a paint is obtained which will really outlast any other paint for a long time. There is no reason why any gases should penetrate through such paint to the iron, and there is no reason, therefore, why the iron should begin to rust as long as the paint is not injured by mechanical action. As soon as such an injury occurs, a spot is created where rust can get in and work its way under the protective coating, peeling it off. This cannot be avoided, and this shortcoming, paint has in common with all other protective coatings of iron.

Mr. Furber also spoke about coating iron with cement. I do not know much about this, but I have seen iron covered with lime, and I think that this method affords a very good protection, where the iron is all entirely enclosed. In that manner, rusting is entirely prevented, because even if water should percolate through the lime to the iron, this water will be entirely free from carbonic acid, and, as you know, chemically pure water will not rust iron.

Mr. C. M. Mills (visitor).—I think there has been a lack of practical investigation for ascertaining the proper coverings for metallic structures. It seems to me, that while it is very desirable to carry out chemical investigations, the results can not be safely accepted unless confirmed by practical tests, scientifically conducted. In specifications for bridges, the quality of steel and iron is usually prescribed in great detail, whereas the very important matter of paint receives little notice. I would like to make a practical suggestion, which, if it meets with approval, will, I hope, some day be carried out. We know that the value of paints depends upon the climatic conditions which prevail where the structure is situated. A paint may resist a dry atmosphere very successfully, and fail in one that is moist. A bridge on the Gulf Coast may be well protected by a certain class of paint, which would fail in another quarter. Again we have structures, such as street crossings in cities, which are subject to corrosion from the gases of locomotives.

It occurs to me that it would be a good plan for this society to secure the co-operation of the chief engineers of some of our leading railroad systems, and establish certain points where experimental tests could be conducted, carefully selecting such points as may afford typical conditions prevailing in various sections of the country. A certain number of structures in those different localities could be painted with compositions selected as the best obtainable by a committee appointed for this purpose.

It would probably be necessary to bar out commercial linseed oil, for it is very variable in quality. It would be advisable, perhaps, to prescribe its manufacture through the various stages, beginning with the quality of the seed.

I appreciate the fact that it might be necessary to use old bridges for these tests, but they could be cleaned in such a way as to place them on a uniform basis. It seems to me that the importance to railway companies of determining the best preservatives for their buildings and bridges would lead them to cooperate in an intelligent effort of this kind. This work might be extended to pipes under ground, and other peculiar conditions, wherever it is practicable to carry on the tests.

Mr. E. K. Landis.—There seems to be considerable difference

of opinion as to the utility of asphalt paint. Some claim that it has great resisting power against atmospheric and other influences. I have had some experience of a rather concentrated nature, which did not show asphalt in a very good light. I allude to the action of laboratory fumes. If there is anything that will rust iron it is laboratory fumes—the temperature is considerably over 70 degrees, and the ordinary iron laboratory apparatus is coated with asphalt japan, that will last in the ordinary laboratory a month or six weeks, and then it will all scale off like the bark of a hickory tree. This seems to show that the asphalt is more or less porous. The rusting takes place through the pores, and the first thing one notices is the whole coat coming off, leaving a complete coating of rust underneath. There is another thing to be said in regard to some suggestions that have just been made about the inauguration of tests. There are quite a number of paints for protecting iron structures against atmospheric and other influences, but the people who are most interested in the application of those paints are not the people who build the bridges, but the people who own the bridges. Of course our friends, the bridge people, wish to get a chance to replace their bridges occasionally, and if they can increase their business in that way, they ought to do it. We cannot blame them, but the people who are most interested are the bridge owners. A great many of the people we class as owners do not seem to manifest the right spirit in the matter. I have known of cases where they have been offered the material for trial. They generally turn it over to a painter, who, though he may be a good painter, is apt to be a man of very narrow prejudices. If he does not happen to like it, or it should have to be applied in a different manner from the way he was used to handling it, he would condemn the paint, and the owners would abide by his verdict. That is not testing the matter in a fair way. The difference that has been alluded to in various situations is very nicely illustrated in Italy, where Etruscan relics which have been buried in the ground for centuries, show little change. But we find in this country, where there is a great deal of anthracite and bituminous coal burned, that there is a decidedly corrosive action. We all remember, probably, that several years ago the Girard Trust had to put a tin

roof on Girard College to protect it from the action of sulphuric acid. That very clearly illustrates the difference in the severity of the conditions. On the other side, where manufactures are not so well developed as with us, and where the amount of coal burned is relatively small, we find metal and marble objects comparatively intact. Here we find them very badly attacked. In Lancaster cemetery I noticed quite a number of monuments, put up to some of our war heroes who are buried there, and the fine work on some of them was completely eaten up. Those monuments had only been put there thirty years ago. Lancaster is a place of comparatively small manufactures. It is not like the city of Philadelphia.

There is another point that was mentioned here to-night in the papers of Mr. Wood, viz., the objection to carbon bi-sulphide and benzine in paints. Why so, I cannot understand. They are both very volatile, and I cannot see that they would have any action at all. They are volatile at a low heat, and would soon dry out.

Mr. James Christie.—When the engineers of the East River suspension bridge considered the preservation of the anchorages, they concluded not to trust posterity, and buried the work so completely in concrete that neither weather nor hand of man could reach it. No pigment or oil will be of avail, if the surfaces of metal are not clean—that is, free from detachable scale or rust. But to obtain efficient treatment, you must convince the purchaser of its necessity or he will not pay the cost of pickling, or similar treatment for large masses.

About thirty years ago the natural oxides of iron became very popular as pigments. It was thought that well-prepared hematite ore, free from sulphur and ground in linseed oil, was invincible, and that a priming coat of red lead was the best foundation. Now Mr. Rinald, as I understand him, says metallic oxides are not a proper pigment, and Mr. Mills says it is hard to get suitable linseed oil.

Visiting a shop in France some years ago, I observed them pass their work between revolving wire brushes, and then over a paint tank between stiff revolving hair brushes, which seemed to do the work effectually, so far as the application of the paint was

Bearing some relevancy to the subject is the question of susceptibility to corrosion of different qualities of steel. I think Riley proved that steel containing considerable proportions of nickel, possessed a high degree of immunity from corrosion. On the contrary, as we approach pure iron, there is a wide belief that the liability to corrosion is increased.

Mr. Rinald.—One more remark about red lead. It is certainly a very good paint under a great many circumstances, but I am sure that where red lead is exposed to locomotive fumes, or to any chemical fumes at all, it will not protect. An experiment can easily be made by painting iron with red lead and exposing it to a small amount of sulphur fumes, when the red lead will be changed into sulphide of lead, which is shown by its turning black. Possibly this is one of the reasons why lamp black is added to red lead paint. Though it can then not be seen that the red lead has turned black, the chemical change will take place just the same. If red lead paint is used in train-sheds where it is exposed to locomotive fumes, it will surely turn black. As to iron oxide, I am not very much in favor of it, and besides there are iron oxides and iron oxides. I am decidedly of the opinion that it would be a great deal better not to paint iron at all than to paint it with some kinds of iron oxide.

Mr. Landis.—Mr. Rinald, who has just spoken, is a paint manufacturer. I have tried some of his paints in my laboratory and I found that everything I have used of his make is entirely unaffected by the laboratory fumes. I would like to ask him how "Bessemer" paint compares with red lead in cost and covering power.

Mr. Rinald.—The article which we manufacture is applied as easily as red lead.

Mr. Landis.—How does it compare in cost per square foot?

Mr. Rinald.—When both are applied correctly, the cost of red lead is higher. Answering another question asked by Mr. Landis, whether benzine is deleterious to iron, I want to say that in my opinion it is, and for this reason: Benzine is used to cheapen paint and make it work more easily. It is what is called in the paint trade an extender; that is to say, it serves the purpose of spreading a given quantity of paint over a larger surface. The benzine

itself evaporates quickly and paint mixed with it will dry rapidly, because it is spread out so much more thinly, but at the same time the parts which had been covered with benzine will be left bare, and consequently the paint will be extremely porous. Benzine is used largely in the manufacture of "paint oil," a cheap substitute for linseed oil. In such a "paint oil," there is just as much benzine as can be gotten into it, without taking away the viscosity of the preparation. Benzine, therefore, is injurious to the iron in so far as it will make paint more porous, whereas the aim should be to make it less so.

Mr. Francis Schumann.—I would like to say first, that I doubt whether a paint will ever be discovered that will be a permanent protection to iron or steel. I believe that the monumental character of a metal structure will depend on continual watchfulness. It should be the duty of the engineer to so construct a building that the vital parts are accessible. In many of the buildings now being erected much attention has been devoted to architecture and construction, while the vital element, the life of the structure, has been, we might say, totally neglected. We see large buildings going up, involving the outlay of much capital, in which the carelessness and neglect to apply proper means for the protection of the important parts of the construction, such as columns, for instance, is almost criminal. Buildings of this kind should be constructed to last for generations, not merely for a few decades.

My experience has been that if cast or wrought iron or steel members, when completed, ready for erection, are heated to a temperature of about 400° F. in an oven built for that purpose, then dipped while hot in a bath of raw linseed oil, giving the pieces a hard coating which forms in three or four days, the metal will resist corrosion most successfully. Certain pieces have remained in perfect condition for upwards of ten years, although exposed to all kinds of weather and temperature.

Assuming the structural parts were so treated and built in a way that all parts could be inspected and repainted at intervals, say with oil only, would it not lessen the danger from deterioration by corrosion? I would like to ask the chemists present, what necessity there would be, under the above conditions, for adding any of the products of lead to the oil? The oil can certainly be applied more readily than thick paint.

In the large buildings now in course of erection throughout the country, in which the columns are simply encased in masonry, either brick, stone or terra cotta, if corrosion should take place at the base of the columns, the life of the building would surely become endangered. Why should we not in the future construct such buildings entirely of metal; why adhere to old methods by enclosing the spaces with masonry? Why could we not use metal sheets in forming the casing of the inner and outer faces of the walls, utilizing the intervening space for heating, ventilation, etc., the outer sheets being electro-plated or painted and lined with some non-conducting material, and having removable panels for obtaining access to columns, etc. The floor and ceiling could be made also of metal plates with a layer of non-conducting material. The interior surface of the rooms might be papered directly on the sheets, while the floor plates could be covered with rubber, linoleum or other fibrous material. The larger furniture could be of metal in order to diminish the quantity of combustible material in the building. Such construction would materially lessen the weight on foundations and avoid the necessity of fire-proofing the constructive parts.

Mr. A. Falkenau.—Mr. Schumann was speaking of the columns encased in modern buildings. I know of two cases in New York, one in particular, in which this question was thoroughly weighed, as to the preservation of the iron work, and a difference existed between the architect and the builder, as regards the durability of the iron. The builder, however, insisted upon having the outside of the building paraffined from top to bottom—the expense of that was some $20,000—simply for the purpose of preventing the moisture from being driven through the wall. Experiments were made which demonstrated that water could be driven through a wall 3½ feet thick, and in consequence of these experiments, paraffine was tried on this large building.

Mr. Rinald.—Some time ago I noticed that they were putting something on the brick front of the Pennsylvania Station on Broad Street. I found out that it was linseed oil and that this was applied to prevent the moisture from getting through the bricks. I want to say in reply to Mr. Schumann that it is a good plan to apply linseed oil when the iron is hot, then you drive out

the water, and at the same time get the oil into the pores of the iron, but when you apply cold oil to cold iron, you cannot get a lasting protection. If you want a temporary protection, linseed oil will answer the purpose; but if you want permanent protection, a fresh coat should be applied at least once a year.

Mr. Schumann.—In regard to the question of cleaning iron, we find the sand blast the most thorough and practical way of treating structural metal.

Mr. Falkenau.—I would like to quote from a letter I received from Mr. T. P. Chandler, touching the subject under discussion, as follows: "In rebuilding a large portion of the Philadelphia Bank, which was among the earliest buildings in Philadelphia in which iron was used in the construction, I found beams taken up which had been in use over forty years, and which were absolutely uninjured by rust. If it is possible to keep the iron perfectly dry, there seems to be no reason why it will not last in buildings for many hundred years."

Mr. W. M. Barr (visitor).—I do not know that I have anything new to add to what has already been said to-night; every phase of the subject having been well considered, so that the few words I may have to contribute, while not new, will be in the line of the general drift, following the speakers of the evening.

At present I am engaged in the erection of a tall building in this city, I am not sure, but probably the highest building in Philadelphia. It is not a wide building, as compared with its height, so that special attention has been given the problem of wind bracing, and in general, questions of form, safety and means of preservation of the structural work have been carefully thought out. First of all a high structure should be a strong one, and for permanent buildings the metal work must have ample thickness. Factors of safety, relating only to the strength of materials under good conditions, are not sufficient. Corrosion is an insidious disease, to which iron and steel are both liable under certain conditions, and the possibility of its occurrence should engage the attention of the engineer when designing framed structures. For this reason alone, my personal preference is for open columns and girders, as distinguished from closed ones, because it is impossible to inspect the inclosed spaces, or to apply a remedy if corrosion is known or suspected.

The line of juncture between the bottom of a column and the I beams on which it rests, at or below the ground line, is a detail demanding careful consideration. In the building on which I am now engaged, all the columns rest upon cast iron bases two feet in depth, the top of each being so placed as to be above the basement floor, the cast iron bases thus occupying that portion of the structure subject to alternating wet and dry conditions of soil and atmosphere.

The construction on the northeast corner of the building includes two cantilevers necessary to bring the building up to the party line. This detail involved much trouble and annoyance, because the footings extend to a depth which included five feet of standing water, nearly all the steel beams required in the footings to support this corner of the building being thus submerged. The bottom was hard gravel, and on this was laid a good bed of concrete. Ten 20-inch steel beams were then placed side by side to cover the whole area, leaving only space enough between them to put in a strong cement grouting, say $1\frac{1}{2}$ inches from flange to flange. This grouting was carefully rammed in place so as to make sure that all spaces were completely filled, after which 15-inch steel beams crossed these 20-inch beams and were treated in the same manner, and so on up to the fulcrums carrying the whole load. The two cantilevers were made of the box girder form with closed ends. The question of preservation is, as will be seen, a vital one. The subject of coatings to prevent rust in wrought iron structures was examined at great length, so far as the excellent library of the Franklin Institute afforded opportunities. The consensus of opinion among writers upon that subject seemed to be that red lead, on the whole, was the best preservative. The specifications were written to include careful cleaning of the metal at the mill and then to give all the metal work one coat of good red lead paint, intending that, after erection, another coat should be applied. Meanwhile the subject received further attention and two paints were selected which were thought to be preferable to red lead on account of easier application and less liability to run and dry in streaks. These two were both proprietary articles and I do not know the composition of either, one being

what is known as "Bessemer" paint, and the other as "Anti-Rust" paint. The latter paint was used on the building and has the quality of being slow drying, a matter of much annoyance at the time, but which afterwards dried out hard, smooth and tough. The necessity for absolute cleanliness at the time of applying the first coat of red lead was made apparent many times during the progress of the work, as much of the material was stored in the weather for several months before riveting in place, and when so put up in the building had to be scraped and repainted. In some instances nearly one-fourth of the surface of a beam had to be thus cleaned, a defect which might have been occasioned by using an old beam covered with red rust, or painting a new beam while it was damp or wet.

The cantilevers are both below the basement floor and were completely bricked in as if laid in a trough or cistern and the whole exterior volume filled in with melted asphalt, free from sulphur, the interior of the cantilevers being filled with a heavy mineral oil carefully tested to see that it was free from moisture, acids or other substances injurious to iron or steel. The beams already referred to as supporting the cantilevers were painted several days before being placed in position, and being thoroughly encased in concrete will, it is believed, last as long as the other portions of the building.

The columns on the outside of the building were built into the brick work and this brick work is now being coated on the outside with a paraffine solution which will prevent the rain, in driving storms, from entering the brick work and making interior surfaces damp. The interior columns are all encased with terra cotta and plastered. The flat portions of the roof are similar in construction to the floors throughout the building, except that a "vulcanite" covering is added to insure their being perfectly water-proof. Such portions of the roof as extend above the main deck are covered with terra cotta and concrete, or "vulcanite," and afterwards treated with parraffine to prevent moisture reaching the metal work.

Mr. Furber.—I do not care to detain the members much longer, except to call attention to a certain feature of this subject which was not fully discussed, namely the use of cement as

a protective covering. I think, as Mr. Schumann has said, that there never will be a paint found that will answer all requirements, and I speak now with special reference to buildings. I think if it were possible—and I believe it is—to thoroughly clean the metal by pickling, to protect it temporarily from corrosion during manufacture and erection, and then to apply a covering of Portland cement directly to the metal, without the intervention of paint, linseed oil or other covering, that if properly applied, the metal work can be preserved indefinitely. Existing literature seems to point to the soundness of this conclusion.

In buildings, where the metal is painted, the oil in the paint is neutralized by the lime in the mortar or cement, which is almost necessarily in contact with it, and paint under such conditions is of little value, and may prove a detriment. This fact seems to have received little attention.

I do not think it feasible or desirable to design a building with the metal work exposed, either inside or out, for examination; architectural and commercial reasons prohibiting.

Mr. Schumann.—I think Mr. Furber must be mistaken in suggesting hydraulic cement. It seems to me that that would be fatal to the iron.

Mr. Furber.—That has never been proven, to my knowledge.

Mr. Schumann.—There is a considerable proportion of water in cement. Lime, on the other hand, affords excellent protection. In some of the older buildings, in which the beams were simply whitewashed, these beams seem to be in as good condition as when they were first put in.

Mr. Christie.—We must remember that cement is variable in its composition and properties. I am not prepared to state, that hydraulic cement under all conditions is a proper protective, but know it to be largely used for preserving without known injury. I recall a particular case where the bases of wrought iron columns were exposed and were being injured, they were covered with cement mortar below and some distance above the ground line, and were found to be well preserved some fifteen years after the application.

Mr. George S. Webster.—The city of Philadelphia, in the

construction of highway bridges over railroads, paints its bridges with three coats of red lead freshly ground in raw linseed oil, care being taken that a proper percentage of purity is obtained; the specification requiring that the pigment must contain at least 95 per cent. of red oxide of lead. The principal difficulty encountered in bridge construction over a railroad is from the gases. In one instance in this city, a railroad company, in order to protect the underside of a bridge from the injurious effect of gases, placed a thin sheet of perforated corrugated iron, and upon that a cement plastering. The ceiling being only 16 feet above the railroad tracks, was very close to the stack of the locomotive, and as the road was on a grade, the exhaust from the locomotives acted like a sand blast and broke the plastering.

In another case, sheet lead was suggested as a covering, and experiments showed, in the case of locomotives burning bituminous coal, that the lead was not affected, but the heat from a locomotive burning anthracite coal was sufficient to melt the lead, which, in the experiment, was placed at the same elevation above the stack of the locomotive as it would have occupied in covering the iron work of a bridge.

There are two bridges in this city in which an effort has been made to protect the metal work by a timber ceiling made of narrow white pine, tongued and grooved boards, painted with an asbestos paint. After the boards were thoroughly seasoned, they were again painted with two coats of paint, so that the iron work is sealed with a lumber coating. The success of this experiment has not yet been determined.

The following written discussion was received:

Mr. Frederick H. Lewis.—Mr. Furber has presented for consideration an important subject. An enormous amount of steel is going into the construction of buildings during the present year, and there is every reason to believe that this amount will increase from year to year until all our buildings, including dwellings, are built with steel frames, to the exclusion of timber. It is entirely clear to thinking men, that in many of these buildings no proper consideration is being given to the protection of the steel frame work which sustains them. The atmosphere of our cities is charged with acid fumes, and a part of

the iron work is believed to be alternately wet and dry from atmospheric changes; the buildings themselves contain a network of steam, water and drainage pipes, and lastly, most of the modern buildings have great electric plants, which may introduce the factor of electrolysis.

That these matters have not received sufficient attention is undoubted, and it is probable that one reason why they have not received attention is because engineers have not been called upon, in most cases, to consider carefully the details of construction. In those cases where an engineer has worked in conjunction with an architect, his duties have generally been confined to designing the foundations and the steel frame work, and have been strictly limited to these matters.

It is a fact, that forms of column construction have been advocated for buildings for the special reason that these columns permitted placing drain pipes, water pipes, electric wires, etc., inside of them, and this apparent advantage has been adopted in a number of buildings. Yet it seems to me that the first principle which should be laid down for the protection of the steel frame work of a building is the careful removal of all these steam and water pipes from the vicinity of important parts of the steel structure. We know that no rusting proceeds more rapidly than that which takes place through the alternate wetting and drying of iron surfaces. A trifling leak in either a water or steam pipe is likely to produce exactly this condition, and hence the importance of keeping these pipes away from the columns and principal girders. Similarly it is of the first importance that electric wires throughout the building shall be carefully insulated, and kept from contact with the steel frame work.

When we come to consider the ordinary external exposures, I think we can at once dismiss from consideration a considerable part of the steel work as not likely to rust. The interior beams, protected by brick or terra-cotta arches, and the interior columns similarly covered with fireproofing material, I consider to be abundantly protected by an ordinary coat of paint, and to require nothing further, so far as atmospheric effects are concerned. Similarly, the beams in foundations, when surrounded by concrete, I think will not corrode. We are assured by competent authority

that neither oxygen nor water alone will rust iron work, even when it is unprotected by paint, and that for rusting to take place it is necessary that there shall be an acid present. As long as the beams are surrounded by cement concrete, therefore, there will be sufficient lime present to absorb any acids in the atmosphere for an indefinite period, even supposing these acids could penetrate to the interior of the mass of concrete. The only parts of the iron work requiring special consideration for atmospheric effects, therefore, are the columns and girders in the outer walls, the interiors of box girders, and occasionally some other parts having special exposures.

It has been stated on the authority of leading architects, that 9 inches of brick or terra cotta is not adequate protection for columns against a driving rain. The question then arises whether a sufficient amount of moisture will get through to actually wet the columns, and whether, with the water, a sufficient amount of acids of the atmosphere will penetrate to destroy the ordinary paints. Perhaps I have stated this proposition too liberally; all iron work is assumed to be painted in buildings, nevertheless, I think it is very rare that a building is completed without having quite a little surface from which the paint has been knocked off, leaving the bare steel. But whether steel or paint, the question is probably only one of degree; if acid fumes and moisture can reach either surface, the steel will probably be destroyed in the course of years. We must either therefore provide, (1) a sufficient thickness of wall to exclude the rains and acid fumes of the atmosphere, or (2) a light impervious wall, or (3) we must find and thoroughly apply a paint which will indefinitely resist corrosion by dilute acids. Now there is no doubt in my mind that the curtain-wall building is the style of construction which is to be used in our large cities. The gain in floor space alone is a very important factor. With floor space renting at from $1 to $2 per square foot, the gain in rentals from curtain-wall construction amounts to thousands of dollars per year, in large buildings, in addition to the saving in construction. Hence I think we must plan for the protection of buildings of this character, and may dismiss the first alternative suggested above. We have then to determine whether 9 inches of brick or terra cotta is sufficient

protection. If it is not, then we must either make the wall impervious or provide a better paint than any now offered.

It seems to me, therefore, that at the present time we need facts rather more than theories. As the principal problems of construction have developed from time to time, American engineers have always met them by experiments to determine the facts, and by such experiments have always been able to develop scientific methods of construction. This new problem must be met in the same way.

I do not care to go into the paint question, because I do not believe that there is very much difference in the value of the better class of paints. Neither do I think we need yet consider pickling or nickel plating. The cost of such work can only be justified by a demonstration that it is necessary.

Prof. Edgar Marburg.—In discussing the preservative power of paints, several speakers expressed the opinion that a paint would probably never be discovered which, without renewal, could be expected to serve as a means of permanent protection to the material covered. This opinion may doubtless be safely endorsed, in so far, at least, as it applies to structures in which the metal work is entirely or largely exposed, as in bridges, train-sheds and open, steel mill-construction generally. The painted metal, in such cases, is freely accessible to the action of acid gases and moisture. Moreover, it is subject to wide ranges of temperature, and often of stress, with incidental vibrations, and there is the ever-present danger that the integrity of the covering will be injured or destroyed through a great variety of mechanical agencies. It is therefore not to be expected that, with future improvements in paint, the existing necessity for its periodical renewal on exposed structures will be in time wholly removed. The permanence of structures of this class resolves itself mainly, if not wholly, into a question of quality of paint and proper preparation of surfaces for its reception. Heretofore bridges have rapidly come to outlive their usefulness, through the remarkable increase of rolling loads. That a limit to this increase will soon be reached, if indeed it has not already been attained, seems wholly probable. For this reason and from the additional fact that bridge-building operations in the future will

be conducted on a scale vastly greater than in the past, the question of better protection through improvements in paints and in methods of application is one of growing importance.

The problem of protection to the steel in modern building construction is, however, essentially different. If the main reliance here rested in the paint, the prevailing practice of encasing the metal work in a manner prohibitive at once to repainting and inspection, must needs be regarded as indefensible. Experience has proven conclusively that the ordinary commercial paints, as usually applied, are short-lived under all conditions of exposure. The durability of steel-skeleton construction becomes therefore primarily a matter of protection to the paint itself, and only in a remote degree one of paint as a protector. Whether such methods of covering as would insure the lasting preservation of the paint would serve also as a permanent protection to clean, unpainted metal, is at least debatable. There seems to be no good reason to the contrary. The paint, in that case, may be regarded merely as a cheap, temporary protection to the metal work during storage and erection, for which the methods of painting now commonly employed would be entirely satisfactory.

There seems to be little ground for expecting any very radical departures from the general methods in vogue at present for protecting the steel framing of buildings. The metal must be enclosed by some kind of refractory material in order to render it more nearly fire-proof. If this covering is made so as to effectually exclude moisture and acid gases, corrosion of the metal cannot take place. It would seem, therefore, that future efforts should be directed mainly towards rendering these coverings impervious, either by the use of improved materials, if necessary, or by external treatment, entirely independent of the paint applied directly to the metal.

Mr. Furber.—I have reviewed with interest Mr. Rinald's able and temperate discussion of the subject of rust and rust preventatives, and am pleased to note that he emphasizes the difference in tendency to corrode between metals which are clean and those which have rust upon them. His illustration of the two pieces of metal is another instance of the good effect of having a clean record to begin on. It has been my practice to

insert a clause in specifications for structural work prohibiting the use of any metal upon which corrosion has begun. The fact has also been shown that if rusting has once begun, the elements necessary for its continuance can be found convenient, under the usual conditions.

Mr. Mills has shown the inconsistency of prescribing with such detail the physical and chemical limitations of the metal, and then neglecting almost entirely the more important matter of its preservation.

Mr. Landis has shown, by several illustrations, the destructive effect of the gases found in the atmosphere in which most of our principal structures are erected.

Mr. Christie, I am pleased to note, makes reference to the subject of pickling, which I think has not yet received the consideration its importance demands, and the beneficial effects of which can be so readily utilized, if its advantages were better appreciated.

Mr. Falkenau and Mr. Barr both instance the attempts toward preventing oxidation by covering the outer walls with a paraffine mixture to exclude dampness, but it would seem that this method is not one which alone would accomplish the desired result, since it can be shown that all the danger is not from the external surfaces but that quite as much is to be feared from internal moisture or dampness, as well as from the same gases which are found in the external atmosphere.

Mr. Lewis, I think, somewhat underestimates the danger from both internal and external exposures. Mr. Landis has shown us that destructive gases are everywhere present, and it is well known that brickwork, terra-cotta and most of the porous or cellular building materials are reservoirs of dampness, and must ever act as condensers of atmospheric moisture. Some little time ago, when some of the internal floor beams were taken out of the City Hall, I noticed that in many places, where the paint had been neutralized by the lime in the mortar of the brick arches, that such places exhibited unmistakable evidences of corrosion. Mr. Lewis' objections to the advantages claimed for certain forms of columns which permit the introduction of water and gas pipes, are well taken, and find prompt confirmation in the minds of many conscientious constructors.

Professor Marburg, I am pleased to note, refers to the desirability of enclosing the columns of a building in a refractory material which shall be at the same time impervious to moisture and gases. This suggestion endorses some of the points I have been contending for, and I am of the opinion that Portland cement can be applied so as to more nearly fill these requirements than any other material at hand or commercially accessible.

Mr. M. P. Wood, in his papers already mentioned, refers repeatedly to the very active influence that mill-scale and imbedded slag have upon the body of the metal, and cites many distinguished authorities in support of his argument. He also mentions the fact that mill-scale is electro-negative to the metal, and that its action is equal to a similar quantity of copper in its corrosive action. No further argument seems therefore to be needed to show how necessary it is to have this scale removed, if durability is desired. I believe when this fact is better recognized, the mills will be found able to undertake its removal with little additional expense, as it is really a very simple matter.

In regard to cement protection, we have long lines of precedents from which to draw conclusions, when it is borne in mind that the internal surface of the hulls of merchant vessels, ocean liners, cruisers, and battle-ships have no other protection against corrosion, than a coating of cement, which is effective as long as it remains unbroken. In the report of the straining of the cruiser "Columbia" in docking in England, and also the docking of the battle-ship "Texas" in Brooklyn, reference is made to the cracking of the internal cement lining. This practice of lining ships with cement does not seem to be as well known among engineers generally as it deserves to be.

ECKLEY BRINTON COXE.

The interval which has elapsed since the telegraph on May 1st announced the death of our fellow-member, Eckley B. Coxe, may have served to lessen the poignancy of grief, but it has certainly done nothing to fill the void which he left in the engineering profession. In fact, time has made the loss the greater, for as detail after detail of his work is suggested, we naturally look for our friend and fellow-member as the instigator of advances.

A Philadelphian by birth, and a graduate of our University of Pennsylvania, Mr. Coxe was naturally connected with the Engineers' Club, and associated with many other technical organizations. Although never an officer of this Club, he had been honored with the Presidency of the American Institute of Mining Engineers, and also with that of the American Society of Mechanical Engineers. During the Centennial Exposition in 1876, he was chairman of a special committee of the American Institute of Mining Engineers, with headquarters in the same block as our Club House, where every facility was offered for forming acquaintances and cementing friendships between American and foreign engineers.

After Mr. Coxe became of age he studied at the Ecole des Mines at Paris, and subsequently at the Berg Akademie at Freiberg. He also spent considerable time in practically investigating mines in Europe, returning to America in 1865, to assume the responsible position of manager of the large coal properties which he and his family inherited. His life work was the development of a business in the mining and shipping of anthracite coal, which attained colossal proportions, and his technical achievements, great as they were, appear to have been equalled by his executive success in the organization and development of the work which he had to do. His activity was prodigious, and the amount of work which he accomplished was most notable.

While Mr. Coxe was well known as a coal operator, and his business acumen appreciated as a director of railways and other

important industrial enterprises, he showed to excellent advantage as a mining and mechanical engineer, and through his efforts many important economies and improvements were introduced. His contributions on engineering topics have been most valuable, and while many of these will long remain as standards, none will bring more honor to his name than the conscientious translation of Weisbach's Mechanics, for which every American engineer must honor him.

His sterling integrity was evidenced when, after he had been elected State Senator, he declined to take the oath of office because it required him to swear falsely, and rather than take advantage of a technicality, he threw aside the honor which his friends and neighbors had brought to him. To the credit of his constituents, his honesty was promptly recognized by a re-election.

Although Mr. Coxe was possessed of great wealth, he preferred living among his people at Drifton, in the anthracite district of Luzerne County, and here it was that he died after a brief illness, in the 56th year of his age.

His achievements in business and in engineering need not be detailed. His many virtues, and the help he was always ready to give to others, are most familiar to those who knew him best. The work which he accomplished is the monument which he raised to his memory as a distinguished engineer. His integrity and activity make the record which recall the successful business man, but his genial disposition and friendly acts are inscribed as enduring tablets in the affection of the many who knew him as a friend, and to whom he had endeared himself.

The name of Eckley B. Coxe will henceforth appear in the too rapidly extending roll at the close of the list of members of The Engineers' Club of Philadelphia, where it will recall to us his ability, his honesty, his achievements, and best of all, his friendship.

CLEMENT LODGE.

Clement Lodge, son of Thomas B. Lodge, was born at Paulsboro, New Jersey, August 10, 1872.

After completing his course of preparatory study at Friends' Central School, Philadelphia, he entered the Sophomore Class of the Engineering Department of Swarthmore College on September 11, 1890, and graduated with the degree of B. S. on June 20, 1893.

He maintained a high standing as a student throughout his college course, and by his accuracy of work, his ready appreciation of the bearings of his studies, as well as by his general manliness and sterling integrity, he gave unusual promise of a successful career in his chosen profession. While ranking high as a student, he was also deeply interested in the general affairs of the college world, its politics, its literary societies, and its athletics, in all of which he took a prominent part by virtue of his acknowledged abilities. As a student, he was distinguished by his natural gifts, by his close application and earnestness, by his clearness of thought and ready comprehension ; as a man, by his uprightness and nobility of mind and character.

After leaving college, he connected himself with the Vulcanite Paving Company, and at the time of his death was engaged in the Bureau of Surveys of this city.

He was a valued member of the Engineers' Club of Philadelphia, and it will seldom lose a constituent who leaves behind him a stronger personality of a rarely sweet and stimulating nature.

It has been said of him among his intimates, that his name had become a synonym for truthfulness, and throughout his long illness, those who were closely associated with him testify that his gentleness and patience endured to the end, and were remarkable in one so young, with so much of worldly success waiting for his active brain and hands. In these general attributes, enduring to the end, may be seen the quiet attitude of an upright soul tranquilly listening for the summons.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, October 5, 1895.—President George S. Webster in the chair. Seventy-four members and visitors present.

The Tellers announced that at the election of this date, Messrs. George H. Birnie, James M. Dodge, E. J. Kerrick, and Charles Piez had been elected to active membership.

Mr. W. P. Dallett called the attention of the Club to the Twenty-third Annual Meeting of the American Gas Light Association, to be held in this city on October 16th, 17th and 18th; and moved that the freedom of the Club House be extended to the members of the Association during their stay in this city, and that they be invited to attend the regular meeting on October 19th. The motion was carried.

Mr. C. L. Prince read an invitation from Mr. A. B. Slater, Secretary of the Association, to the members of the Club, to attend their meetings at the Continental Hotel upon the dates above named.

The House Committee announced the improvements that had been made during the vacation months, in the furnishings and method of heating the Club House. In the absence of the Chairman of the Library Committee, the Secretary explained, in answer to a question, that work had been begun in arranging the library so that it could be easily used for reference, and that this work would be rapidly pushed to completion.

Mr. John Birkinbine, Chairman of the Special Committee appointed for this purpose, presented a memorial of Eckley Brinton Coxe, late member of this Club.

Mr. William H. Dechant read a paper on "Submerged Pipe-line for the Pennsylvania Sanitary Sewerage Company, at Reading, Pa," describing the method of construction across the Schuylkill River. The details of the work were fully illustrated by a series of photographic views projected from the lantern.

These, and other methods of laying lines of pipe were discoursed orally by Messrs. John Birkinbine, Allen J. Fuller and the author.

The President called attention to the series of practical talks on electricity to be given at the Club House, on the Saturdays alternate with Club meetings, commencing on October 12th, at which time Mr. Carl Hering was announced to speak on "Electrical Energy; Terms, Properties and Calculations."

The Chairman of the Information Committee added that the electric current would be run into the building, and by it and other means these talks would be illustrated as fully as possible.

Regular Meeting, October 19, 1895.—President George S. Webster in the chair. Seventy-nine members and visitors present.

The Secretary exhibited a wall map of Fairmount Park, lately presented to the Club by Gen. Russell Thayer, and, upon motion, it was ordered that the Club's thanks be extended for this gift.

A general discussion on the subject of "Durability of Iron in Modern Building Construction," was opened by Mr. W. C. Furber, who was followed by Messrs. C. D.

Rinald, C. M. Mills, E. K. Landis, James Christie, F. Schumann, Wm. M. Barr, and Geo. S. Webster.

At the close of the discussion, the President announced that on the evening of October 26th, Mr. Thomas Spencer would speak on "Electric Lighting Installations," and, on November 9th, Mr. C. W. Pike would explain "The Electric Transmission of Power."

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, September 21, 1895.—Present: Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors C. L. Prince, Henry Leffmann, William J. Hoyt, and the Secretary.

The President having sent word that he would be unable to attend, Vice-President Falkenau occupied the chair.

The Treasurer's Reports for June, July and August showed:

Balance from May	$1,428 75
Amount received during June	213 55
	$1,642 30
Amount expended during June	601 53
Balance June 30	$1,040 77
Amount received during July	231 75
	$1,272 52
Amount expended during July	834 44
Balance July 31	$438 08
Amount received during August	92 59
	$530 67
Amount expended during August	90 00
Balance August 31, 1895	$440 67

The Secretary reported that the memorials of Messrs. Lodge and Coxe would be ready for presentation at an early date, and that Mr. Murphy, Chairman of the special committee to prepare a memorial of the late Capt. S. C. McCorkle, had promised to present the same as soon as possible.

A communication was read from the American Society of Mechanical Engineers, and a transcript from its minutes with reference to the death of its late President. As the latter was not a member of this Club, the Board deemed it unwise to take any action in the matter.

A communication was presented from Mr. Thos. Egleston, Chairman of a Special Committe of the American Meteorological Society, recommending a metric gauge for general adoption. No action was taken.

A communication was also presented from Mr. O. Chanute, accompanying a letter of thanks from the Director of the Society of German Engineers, with a photographic memorial of its appreciation of the reception tendered to members of this society during the World's Fair at Chicago.

The Membership Committee reported that there were four applications awaiting

action, and Mr. Prince suggested that it might be well to include the record of applicants on the voting slips, in order that voters might have fuller information. The consideration of this matter was referred to the Membership Committee.

The Library Committee reported progress in the business of arranging the library in proper shape for use.

The House Committee reported that more sanitary plumbing had been put in the second floor, at the expense of the Club, and that the Girard Estate had put in a new heater; that a new arrangement of tables would also be made at the next meeting, for serving the lunch, which would probably give more room to both caterers and members.

The Information Committee reported that at the meeting of October 5th, Mr. William H. Dechant would read a paper on "The Submerged Pipe Line for the Pennsylvania Sanitary Sewerage Company, at Reading, Pa."

Regular Meeting, October 19, 1895.—Present: President George S. Webster. Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Edward K. Landis, C. L. Prince, Edgar Marburg, Henry Leffmann, William J. Hoyt, and the Secretary.

The Treasurer's Report for September showed:

Balance from August	$440 67
Amount received during September	207 50
	$648 17
Amount expended during September	507 09
Balance September 30, 1895	$141 08

Upon motion, the Treasurer was instructed to notify, on November 1st, all members more than one year in arrears, that in accordance with the first paragraph of Article VIII, Section 1, of the By-Laws, the names of all delinquents would be considered at the November meeting of the Board of Directors.

The Treasurer was also instructed to put the account of Hoff & Fontaine in the hands of a collector, as he found it impossible to obtain payment in any other way.

The Secretary read a letter of thanks from the American Gas Light Association, for the freedom of our Club House during their convention in this city.

The resignation of Mr. Howard Sellers was read, and ordered to be presented to the Club at its next business meeting.

The Finance Committee in its report stated that the collectible assets for the balance of the year would approximate $1,422.00, while the probable expenses would reach $1,589.00

The House Committee reported that the electric current had been introduced to the meeting room from the Edison's Company's mains, through Heppe's piano warerooms, and upon motion a vote of thanks was extended to Mr. Heppe for his courtesy in this matter.

This Committee also stated that the best form of electric lantern could be purchased for $134.00, and after considerable discussion the Committe was instructed to ascertain the prices of other styles and report to the Board before ordering.

The Information Committee stated that Mr. Hewitt, who had consented to deliver a talk on Electrical Power Transmission, would prefer to have his lecture on the

evening of Friday, November 22d, to be followed by visits of inspection to power houses on Saturday, November 23d, and upon motion the Committee was given power to make the change, if they thought it desirable.

This Committee also stated that a stenographer had been engaged to take down the discussion at this evening's meeting, and upon motion the Committee was authorized to obtain his services whenever necessary, at a compensation of $5.00 per meeting.

CONTRIBUTIONS TO THE LIBRARY.

From June 15, to October 15, 1895.

From American Institute of Civil Engineers.

Transactions, Volume XI, 1894.

From American Institute of Mining Engineers.

Transactions, Volume XXIV, 1895.

From Aqueduct Commission of New York.

Reports of the New Croton Aqueduct Reservoirs and Dams, 1887 to 1895.

From Chief of Engineers, United States Army.

Index to Reports, 1888–1892.

From City Engineer of Toronto.

Annual Report, 1894.

From E. L. Corthell.

Résumé of Correspondence from Engineering Societies, relating to Establishing Closer International Relations.

From Department of Public Works of Chicago.

Nineteenth Annual Report with Mayor's Message, 1894.

From Desmond Fitzgerald.

Short Description of the Boston Water Works.

From Forestry Department, Washington, D. C.

Report on the Use of Metal Railroad Ties and on Preservative Processes and Metal Tie Plates for Wooden Ties—Tratman.

From Geological Survey of Canada.

Annual Report, Volume VI, 1892–1893.

From Herman Haupt.

Long-Distance Transmission of Power.

From Institution of Civil Engineers, London.

Abstracts of Papers in Foreign Transactions and Periodicals.
Brief Notices of Works—Vernon-Harcourt.
Caissons and Gates for Dock Entrances—Wales.
Circular Wheel Teeth—Sharp.
Cylindrical Bridge Piers—Young & Edwards.

Cyanide Process—Butters & Smart.
Delta of the Danube—Vernon-Harcourt.
Development of the Experimental Study of Heat Engines—Unwin.
Dry Dock Equipment—Redman.
Experiments on Centrifugal Fans—Donkin.
Flow in Sewers—Crump & Bruges.
Footways—Cooper.
Glasgow District Subway—Stewart.
Heat Insulators—Jamieson.
Kidderpur Docks—Bruce & Apjohn.
Light Railways in Australasia—Forster.
Main Drainage of Edinburgh—Fairley.
Maintenance of Macadamized Roads—Aitken.
New Papaghni Bridge—Thompson.
New Westminster Water Works—Hill.
North Shore Water Supply, Sydney, N. S. W.—Blomfield.
Portland Cement and Concrete—Sandeman.
Powers of Lighthouse Lights—Brebner.
Railway Rolling Stock—Hill.
Regulation of Steam Engines—Richardson.
Steam Engine Economy—Davey.
Steel Sleepers in Queensland—Griffiths.
Strength of Shafts—Popplewell & Coker.
Tarred Footpaths in Rural Districts—Hooley.
Torpedo Boat Destroyers—Thornycroft & Barnaby.
Transmission of Power by Electricity—Robertson & Hay.
Widnes Sewerage—Sinclair.

From Henry Leffmann.

Criticisms on Some Methods of Reporting Water Analysis, with Suggestions for a Uniform System. Expert Testimony.

From Library Company of Philadelphia.

Bulletin, September, 1895.

From Link Belt Engineering Company.

Modern Methods of Fuel Handling in Locomotive Coaling Stations, Industrial Electric Light and Street Railway Power Plants.

From Liverpool Engineering Society.

Transactions, Volume XVI, Twenty-first Session, 1895.

From Benjamin Smith Lyman.

Folds and Faults in Pennsylvania Anthracite Beds.
Report of the New Bed of Bucks and Montgomery Counties.

From Master Car Builders' Association.

Proceedings, 1895.

From McGill University.

Announcement of the Faculty of Applied Science for the Session 1895-1896.

From North of England Institute of Mining and Mechanical Engineers.

Report of the Proceedings of the Flameless Explosives Committee, Part I—Air and Combustible Gases.

From Patterson & White.

Club Directory, 1895.

From L. Y. Schermerhorn.

Reports on Flood Protection for the City of Williamsport.

From Society of Heating and Ventilating Engineers.

Transactions, Volume I, 1895.

From United States Civil Service Commission.

Eleventh Report, July, 1893 to June, 1894.

From United States Coast and Geodetic Survey.

Bulletin No. 34—Distribution of the Magnetic Declination in Alaska.

From United States Geological Survey.

Bibliography of North American Paleontology, 1888-1892—Keyes, Bulletin No. 121.
Devonian System of Eastern Pennsylvania and New York—Prosser, Bulletin No. 120.
Fourteenth Annual Report, Part I—Report of Director, Part II—Accompanying Papers.
Geographic Dictionary of New Jersey—Gannett, Bulletin No. 118.
Geological Reconnoissance in Northwest Wyoming—Eldridge, Bulletin No. 119.
Geology of the Green Mountains in Massachusetts—Pumpelly, Wolff & Dale, Monograph XXIII.
Mollusca and Crustacea of the Miocene of New Jersey—Whitfield, Monograph XXIV.
Productions of Iron Ores in Various Parts of the World—Birkinbine.
Results of Primary Triangulation—Gannett, Bulletin No. 122.

From University of Wisconsin.

An Experimental Study of Field Methods, which will insure to Stadia Measurements Greatly Increased Accuracy.

From George S. Webster.

Annual Report of the Bureau of Surveys, 1894.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit is given the PROCEEDINGS.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XII.] JANUARY, 1896. [No. 4.

[The paper on "The Water Supply of Rome," by Dr. Henry Leffmann, Active Member of the Club, read at the meeting of November 2d, is withheld from publication pending the securing of additional data and the preparation of some illustrations.]

XVII.

PAINT AS A PROTECTION FOR IRON.

By E. A. CUSTER and F. P. SMITH.

Read November 16, 1895.

THE question of what constitutes the best protection for iron is not a new one by any means. Paint in some form or other has been generally accepted as being the prime desideratum, not only because of the comparative cheapness, but also on account of the ease of application. Manufacturers, builders, designers and iron and steel workers shrink from a process that involves the use of a special treating plant or the expenditure of more than a minimum amount of time and money. The protective coating they demand must not only be a safe coating for the metal, but must also be a good base for subsequent ornamentation. The necessity of this covering is obvious, and its requirements are many, but they all rest upon the simple basis that it must prevent rust. Iron rusts. There are certain theoretical conditions to

which this statement does not apply, but these are only met in the laboratory. Iron rust, in the general acceptation of the term, means not only the formation of rust on the surface of metallic iron exposed to ordinary atmospheric conditions, but also the corrosion of iron by such substances as sulphuric or sulphurous acids, muriatic acid, or any corrosive constituent of the air.

Past experiments have conclusively demonstrated that bright iron does not rust when exposed to a dry atmosphere of pure oxygen, or of pure carbonic acid gas, or the two mixed. The introduction of a very small percentage of moisture, apparently, is not sufficient to start up the rusting process; but if a piece of rusty iron be substituted for the bright iron in this experiment, it will be found that only the slightest trace of moisture is necessary in order that the rusting action, once commenced, may be continued. It is probable that this action is not solely due to the corroding influence of the rust already present, but also to its power of absorbing oxygen, and condensing moisture.

In this connection it may also be well to state that Prof. Lewes, in his report to the Admiralty Board on the corrosion of ships bottoms, records the presence of minute particles of magnetic oxide of iron at the bottom of the pits which occurred in the iron surface, showing that a galvanic action had been set up very similar to that produced by metallic copper when in contact with the iron. While this is more especially true of iron surfaces which are entirely immersed in water, it must be remembered that structural iron in many cases becomes saturated with condensed moisture, and that the conditions are then practically the same. This introduces another complication into the consideration of the phenomenon of rusting.

The chemistry of the rusting of iron has been widely discussed, and the fundamental principles underlying it are to be found in many scientific works. The question has been treated at so great a length, however, that frequently the discussion becomes so involved as to obscure the main points of the matter.

Prof. A. Crum Brown, in an interesting paper written some seven or eight years ago, gives a lucid explanation of this phenomenon. Briefly he states it thus:—"It should be noted that the carbonic acid dissolved in the liquid water which is necessary for

the rusting is not used up in the process. It is given off during the oxidation of ferrous bi-carbonate to ferric hydrate, and is thus ready to act on the new surface of the metallic iron. The continuation of the process is not, therefore, dependent on new carbonic acid absorbed from the air, but the original carbonic acid, if not removed, can carry on the process indefinitely, as long as liquid water is present and oxygen is supplied. Once the process is started it goes on more rapidly, because the porous rust not only does not protect the iron, but favors, by its hygroscopic character, the condensation of water vapor from the air as liquid water. A piece of iron, therefore, which has begun to rust will continue rusting in an atmosphere not saturated with water vapor,—an atmosphere in which a piece of clean iron will not rust, because liquid water will condense from such an atmosphere on the hygroscopic rust, but not on the bright iron."

From this it will be seen that any covering that is absolutely impervious to moisture will, when applied to clean iron, prevent rusting under atmospheric conditions in which corrosive elements are wanting. Now, if this were the only requirement, the solution of the problem would be easy, but it is ony the beginning. Iron is not an inert mass by any means; it is full of life and movement, and the covering perforce must adapt itself to each change of condition, without loss of its original efficiency. There is no atmospheric condition to which iron is not subjected, and the protective covering that is to meet these conditions must be cheap and easily applied. A paint, or combination of paints, would seem to be the logical outcome of the problems involved.

To quote Mr. Woodruff Jones:—"The requisites of a good paint for the preservation of iron and steel are:

"*First.*—It shall firmly adhere to the surface and not chip or peel off.

"*Second.*—It must not corrode the iron, else the remedy may only aggravate the disease.

"*Third.*—It must form a surface hard enough to resist frictional influences, yet elastic enough to conform to the expansion and contraction of the metal by heat or cold.

"*Fourth.*—It must be impervious to and unaffected by moisture, atmospheric and other influences to which it may be exposed."

With the preceding facts and requirements in view, the work of producing a paint that would absolutely protect iron was undertaken. It was early determined that the covering should consist of two distinct elements, the first of which should possess the adhesive and elastic properties, and afford a safe and reliable base for the application of a second coating that would be hard, elastic, acid proof, and absolutely impervious to moisture. There is no paint known that would meet the first requirement so fully as good red lead and linseed oil. Experiments have proven this, and modern chemistry affords the correct explanation, but unfortunately red lead and linseed oil, while sticking firmly to the surface of iron, and while possessing the necessary elasticity, form but a comparatively poor protection from the effect of moisture.

To fully comprehend this, it will be necessary to go somewhat into the chemistry of paint, and the action of the pigment upon the linseed oil. Red lead is what may be termed an active pigment, *i. e.*, it possesses the property of saponifying linseed oil; in other words, it forms a metallic soap, or combination of the lead with the fatty acid of the oil. To better understand this action, it should be remembered that linseed oil is a combination of glycerine and a fatty acid, or, in other words, it is a liquid fat. The soap, which is ordinarily used for washing purposes, is prepared from fats, such as tallow or grease, by the action of an alkali upon them. This action is two-fold. In the first place, the alkali combines with the fatty acid to make the soap, and the glycerine which was originally confined in the fat is liberated, and is run off in what is termed by soapmakers the spent lye. This spent lye is the source of most of the glycerine of commerce. Now, when a pigment combines with linseed oil, the same action takes place, viz., a metallic soap is formed, and the glycerine is liberated. This glycerine is not a perfectly stable product. It is soluble in water, and is volatilized by heat. Should the saponification be gradually formed after the paint is applied, and during the process of drying, the film will probably be rendered more or less porous by the escape of the glycerine and the action of water which dissolves it. No research on linseed oil has ever attained the same thoroughness as that made by Muelder some time ago, who showed that, during the process of dry-

ing, the oil absorbed oxygen from the atmosphere, and at the same time gave off carbonic acid, acetic acid, formic acid, and probably water vapors. The slow escape of these compounds through the partially dry film may, in a measure, account for its porosity. It would seem, upon hasty consideration, therefore, that an inactive pigment would be preferable for use in a paint for protecting iron. It must be remembered, however, that when an active pigment is used, the soap formed by its action on the linseed oil is capable of taking up a small percentage of moisture, which is almost invariably to be found on the surface of iron, without material injury; so that up to a certain point the presence of the soap is desirable in the paint.

Red lead possesses an advantage over any other active pigment in the fact that not only does it combine with the fatty acid of the oil, but with the glycerine as well. In this way, any volatilization during drying is largely prevented. The glycerine present is rendered insoluble; the film formed possesses great tenacity, elasticity and adhesiveness, and the drying of the paint is of a double nature, as it sets, in some respects, like a cement, besides exhibiting the ordinary phenomena of oxidation common to the drying of all linseed-oil paints.

It has been claimed that a coating of red lead simply induces oxidation of the iron surface underneath, and the claim supported by photographs of the scale produced, apparently showing that oxidation has gone on very actively under this coating of red lead. It has never been claimed for red lead that it would, if painted over a rusted surface, prevent the further deterioration of the metal underneath. In fact, it will be the endeavor to show with much clearness that the dry film of red lead and linseed oil is porous, and in that very point, it fails in one of the most important essentials of a proper covering for iron, unless this defect be remedied by a second coating of paint, which will dry with an absolutely impervious and water-proof surface.

It has been further objected to red lead, that the percentage of oxygen which it contains, and the fact that it is used in increasing the drying properties of raw linseed oil, render it unfit for use as a pigment. As a matter of fact, red lead contains less than 10 per cent. of its weight of oxygen, while oxide of iron contains some-

thing over 30 per cent. The drying action of red lead on oil is probably entirely dependent upon the saponification of the oil; the presence of a small percentage of linoleate of lead being sufficient to dry a large quantity of linseed oil by inducing oxidation. It is justly claimed in support of red lead that this property of saponifying the oil, not oxidizing it in its true sense, renders it one of the most valuable pigments for painting structural iron, when used as a first coat.

The question of porosity was partly considered by Dr. Dudley in his experiments on the water-absorptive power of the dried film of linseed oil. He obtained direct proof of the fact that dried linseed oil is not water-repellant or water-resistant. Pieces of glass coated with ordinary linseed oil were allowed to dry and harden for a couple of weeks. These coated glasses then had water placed upon them and were covered, so that the water could not evaporate. At the expiration of twelve hours it was found that the dried linseed oil had soaked up the water, and wherever the water had touched the coating, it presented the appearance of a shriveled apple. On allowing the water to evaporate, the coating dried down again to its place; but it was quite evident that under the action of water an apparent disintegration had taken place. Further experiments showed that the porous character of the film was modified to a considerable extent by the addition of finely ground red lead, but it still remained sufficiently absorbent to preclude the idea of using red lead and linseed oil *alone* as a covering for the iron.

This point of Dr. Dudley was corroborated by a series of experiments, somewhat on the same lines and further extended with a view to ascertaining whether a vehicle could be produced that would safely mix with red lead without endangering its adhesive quality, and at the same time render the mass water-resistant. This attempt proved unsuccessful, as by so doing the many valuable properties possessed by the combination of red lead and linseed oil were sacrificed.

Attention was then directed toward producing a paint which could be used as a second coat, and which would possess the necessary waterproof, elastic and other qualities. This investigation, as has been said, corroborated Dr. Dudley's experiments,

but carried them much further, with a view to determining not only the water absorptive power of a dry film of linseed oil, but if possible, its actual porosity. The complete data and notes of these experiments have not yet been compiled, neither are they considered as having been brought to an end, but they have so far progressed that it is possible to measure with comparative accuracy the relative porosity of the dried film of linseed oil when mixed with different pigments, as compared with the dried film of the vehicle, which was finally selected as offering the nearest approach to an ideal outer covering for iron work.

The question of the vehicle once determined, the pigment became the next consideration. The ordinary oxide of iron, from its extreme cheapness, seemed at first the proper starting point of the experiments. At the very outset serious obstacles to its use, however, were encountered. The fact was soon recognized that iron oxide possesses great power to destroy organic matter. In determining its action on a film of linseed oil it was found that, long before the destruction of the film was complete, it had yet sufficiently far advanced to seriously affect the elasticity of the film, which soon became so dry and brittle as to totally lose its power of expanding with the iron. This made it necessary to go over the premises again, and the fact became apparent that iron oxide was, in itself, not only in a direct, but also in an indirect, manner a promoter of rust. The conclusion was finally reached that it was only logical that one of the constituents to be avoided in a paint for iron would be ordinary ferric oxide or iron rust. This line of argument has, of course, been presented before, but it should be remembered that the desire was to take as little as possible for granted, and to dispose of any fallacies, should they exist, in the usually accepted axioms, in approaching this problem. Much time was spent in obtaining conclusive proof of the correctness of this view, and its soundness was finally conclusively demonstrated. This naturally led up to the fact that the pigment in itself must be inert so far as the iron is concerned, for while the intention was to prepare a second coating only for the iron, to be used over a foundation coat of red lead, the fact was recognized that in many cases it would probably be employed as a sole protective coating.

In addition to this, it is necessary to produce a paint which will be hard enough to resist frictional influences and be insoluble in acids. To this end there should be incorporated in the pigment a material which resists frictional action in the highest degree, which it is practically impossible to destroy, and which is to all intents and purposes absolutely insoluble in any of the known solvents.

Many utterly worthless paints largely owe whatever measure of success they may have obtained to the prevalent impression that they are cheap. Now, to the thinking man, the question of cheapness does not necessarily mean a low first cost, but the effective covering power must be considered. The spreading power, *per se*, is not necessarily an element of cheapness; as a film may be so thin when well brushed out, as to give little or no protection. On the other hand, when the film produced is of the proper thickness and kind, the spreading power becomes a very important element of cost.

A further serious objection to these paints, which usually closely approximate in color the surface of the iron itself, is their tendency to sag when applied to vertical iron surfaces. Now, much of the structural iron to be painted is in an inclined or vertical position, so that this point should be carefully considered. It is true, that red lead, if improperly ground or mixed, also exhibits this tendency to sag, but should separation take place, it is readily detected, as the iron shows up prominently in those places where it is not thoroughly covered. When this is not the case, the color of the iron and painted surface are so nearly alike that only the closest inspection will reveal where it is improperly covered. A serious source of danger exists at these points, as the linseed oil is unprotected by any pigment, and rusting soon commences.

The fact of the porosity of the film of linseed oil, while an extremely important consideration in the making up of a proper paint for iron, has led to the foisting upon the market of a large number of worthless paints for this purpose, which, under the pretense of avoiding this porosity, have been made up with a vehicle, consisting largely of rosin oil, or some other equally inefficient substitute.

And now there is one point which should be very seriously considered when the protection of iron is the desired end, and that is the presence of mill-scale or iron rust. No paint, however good, is worth a cent a ton for the protection of iron when painted over mill-scale. Mill-scale is brittle, and will chip away from the iron under the expansion due to the ordinary effects of heat and cold, and when it does chip away it will carry the paint with it, and thus expose the iron to the effects of rust. The preceding facts are so well known, that it is the practice of architects and engineers to specify and insist on the absolute removal of mill-scale from the iron before it is painted. Sometimes it is effected by immersing the iron in dilute acid and using wire brushes, and afterward either washing off or neutralizing the acid that may remain on the iron surface, and which would not only continue the corrosive action on the iron, but would be destructive to the film of the paint. In ordinary practice, it has been found sufficient, in structural iron especially, to brush it carefully and thoroughly with a good wire brush, and then to apply the paint. The investigations have gone so far in this matter that it has been found unnecessary to remove the fine velvet-like rust, or the rust that has not commenced to scale, as long as it is completely covered with a paint, proof against acids and moisture. It is better, however, that the absolute removal of the rust and scale be specified in every situation where structural iron is necessary. Too great stress cannot be laid upon this point. It is absolutely essential.

Further, a good paint, and one that will thoroughly protect iron, should possess the quality of firmly adhering to a hot iron surface. This is especially true of steam pipes, boiler fronts, etc. It must not only be able to stand a high heat, but in addition should be able to accommodate itself to the surface of the pipe below the freezing temperature, and this without loss of its original integrity and elasticity. Here are some pieces of pipe that were first coated when cold with the protective paint of which mention has been made. After being allowed to dry, they were screwed on to a steam pipe and live steam at a temperature of 340° was passed through them for about an hour. The pipes were then painted while hot with the same preparation and allowed to stand

two hours. Steam was then shut off and the pipes dipped in a mixture of salt and ice and allowed to remain until thoroughly chilled. How well the paint stood can be seen from these samples. Steam pipes running through buildings where sulphuric acid is concentrated and which are constantly filled with the fumes from the acid have been coated and to-day show no signs of deterioration; whereas, formerly it seemed impossible to get a pipe, other than lead, that would stand the work. Boiler fronts have been given one coat when hot and this coat has lasted for eight months, without any sign of splitting or cracking. There is an iron bridge in the factory under which switching engines pass six or eight times a day. This bridge was painted some three years ago, and to-day the surface of the paint seems absolutely unbroken. Just to one side of this bridge, directly over the center of the track, are plates of iron coated with various protective paints, including red lead and linseed oil, and some of the other mixtures that were tried in the search for an ideal paint. There is only one of these plates that is in good condition to-day, and that is the one that was coated with the paint finally selected as being the best protection for iron, having first been primed with red lead.

And now a word in conclusion, and to repeat, perhaps, what has already been said, and that is, that if you wish to protect iron perfectly from the effect of rust, it is essential that this iron be given a coating that will exclude moisture. Moisture is the active principle in rust. The three elements that produce this rust are carbonic acid, oxygen and water. Carbonic acid and oxygen alone are harmless. It is not until they are brought into contact with water that the rusting process begins. Hence, to protect iron from rusting, the coating applied must be waterproof. To protect iron from corrosion, the coating must be acid-proof. To protect iron from abrasion, the coating must be hard, yet elastic.

DISCUSSION.

Mr. G. B. Price.—Do I understand that the first coat is intended to fill up the pores of the iron and the second to give a hard surface?

Mr. F. P. Smith.—In a certain sense, yes. Iron, of course, is not as porous as wood, or at least not in the same sense, but the function of the first coat is to cover the surface with a tough, elastic film which will adhere closely to the iron under all conditions and which will present a surface suitable for the application of the second coat, the special function of which is to resist the action of the atmosphere by presenting a hard, impervious, enamel-like surface.

The most severe test to which this paint has been subjected was its exposure for very nearly four years to the fumes from both a large sulphuric and a muriatic acid plant, and it shows no signs of deterioration yet. The gloss which is apparent when the paint is first applied has disappeared, but a careful microscopical examination revealed no pores or cracking. When the paint was removed by scraping, it was seen that the iron had been perfectly protected. Ordinary paints, under such conditions, would not have lasted more than two years.

Mr. C. W. Pike.—Has this paint been used for the protection of smoke-stacks?

Mr. Smith.—It has been used successfully for the protection of smoke-stacks; also for boiler fronts and in places where a red heat is not maintained. Sustained red heat would, of course, burn off the vehicle and leave the iron perfectly bare. The paint does not crack, however, under heat.

A Member.—Is the first coat applied at the shop?

Mr. Smith.—Ordinarily, yes, and the finishing coat is put on after erection, because this coating is very liable to be injured in handling the large pieces of structural iron.

Mr. J. C. Trautwine, Jr.—Our experience in applying melted asphalt to concrete surfaces may be of interest, although not directly bearing upon the subject at issue. It has been found absolutely essential to apply, first, a priming coat of asphalt dissolved in benzine or gasoline. We used, first, 50 per cent. of gasoline and 50 per cent. of the liquid asphalt, but that proved much too heavy, and we are now using 70 per cent. of gasoline. This makes quite a liquid wash. The solvent acts as a vehicle carrying the particles of asphalt into the pores of the concrete. After this priming coat is thoroughly dry, that is, after all the

solvent has evaporated, the melted asphalt is poured on hot and spread with brooms. Thus applied, the asphalt adheres tenaciously to the concrete surface, whereas, if it is applied directly to that surface, it breaks off very readily. Coal-tar, also, has been used as a priming coat.

Mr. C. D. Rinald.—What Mr. Trautwine has just said is true of almost all paints. Paint for protection should not be laid on too heavy, as it is then much more liable to be injured by mechanical action, such as the effect of anything striking against it.

Mr. Smith.—So far as the use of benzine on iron is concerned, we have found it objectionable, for the reason that it is very difficult to get benzine which is perfectly volatile. After evaporation, it usually leaves a greasy surface, which, though not objectionable in the case of porous substances like cement or concrete, is disadvantageous in the painting of iron work.

Mr. Rinald.—Gasoline or benzine should not be used in painting iron, because their evaporation will leave bare spots where rust can set in. In the case of concrete, the conditions are of course entirely different.

Mr. Trautwine.—Because there is in this case no rust.

Mr. Rinald.—Yes, and because the benzine carries the asphalt right into the pores of the concrete.

Mr. Smith.—The great objection to coal-tar is that it will not stand exposure. This is well illustrated by a comparison between asphalt pavements and the coal-tar and gravel pavements which were used some years ago. The latter, after exposure for a comparatively short time, cracked and completely disintegrated under the action of water, frost and heat.

Mr. Pike.—I would like to inquire whether this paint would be suitable for the protection of copper as well as iron.

Mr. Smith.—I know of no reason to the contrary, but my personal experience with copper has been that ordinarily its wasting away was so very slight and so gradual, that it required practically no covering, except for ornamental purposes. My experience, however, has been chiefly confined to ships where copper is used for the very reason that it does not waste away rapidly.

Mr. Pike.—So far as resistance to the action of acid fumes is

concerned, I suppose your paint will resist far longer than the copper, and I presume there is no reason why it would be less effective when applied to copper.

Mr. Smith.—No, sir.

Mr. Pike.—Would you in that case recommend the use of the priming coat of red lead?

Mr. Smith.—I can only answer that question theoretically, but I see no objection to the use of red lead in this case, and unless there be some special objection, with which I am unacquainted, I would recommend its use.

Mr. Rinald.—The authors of this paper advise the use of red lead as a priming coat, one reason being that the second coat of paint may adhere better. I do not see why a paint could not be made—in fact it is made—so that it will adhere to the iron without anything under it. Even when the iron is very smooth, a paint ought to adhere just as well without a priming coat.

Mr. F. Schumann.—Some ten years ago, a person exhibited at our works a liquid for coating iron with a glossy covering of different colors, which stood the test of being immersed in water and different acids. We bought the secret of the composition of the liquid from him, which was simply African Sandarac gum dissolved in alcohol, the colors being produced by the admixture of aniline dyes. We afterwards painted a large steam engine with the mixture, which without pigment was quite transparent, although slightly dimming the polished surfaces, but otherwise clean and free from rust. Some two years afterwards the engine was sold, requiring certain changes that necessitated the removal of the gum coating. It adhered so tenaciously, however, that this proved quite expensive, requiring the use of a hot concentrated lye solution applied with scrubbing brushes. During its use it stood exposure to steam, gas and moisture, prevailing to a considerable extent in the shop where the engine was stored. Why are these vegetable gums not well suited for the protection of iron?

Mr. Rinald.—A similar preparation, largely used for many purposes, is gum shellac dissolved in alcohol. It makes a strong coating, but I do not think that any gum will stand exposure to the weather for any length of time. It will crack and peel off.

Mr. Smith.—It is unfortunately true of almost all vegetable gums which are completely soluble in alcohol, that while they present a very pretty appearance, they are practically worthless when exposed to the weather. In the better grades of varnish these gums are not used for the reason stated. Even when placed on wood, their life is comparatively short.

Mr. Max Livingston.—If the paint Mr. Trautwine mentioned is good, I should think that the trouble about the benzine could be overcome. What objection would there be to the use of bi-sulphide of carbon?

In all this discussion no attention has been called to the difficulty of painting steel and the comparative ease of painting iron. It has been my experience that paint on iron will last considerably longer than on steel, especially if the steel is used in tanks, and those tanks be filled with water. If filled with oil, there is comparatively little difficulty, but when filled with water the steel will rust very quickly. With steel, the best of paints will chip off, under the same atmospheric conditions under which they would last when applied to iron. We cannot find any reason for this, but the fact remains that we have found more difficulty in keeping steel tanks from rusting than iron ones.

Mr. Smith.—I do not think that I could give any lucid or valuable explanation. The only explanation which I can offer and which I confess is somewhat lame, is simply a statement of the well-known fact that some metals rust more quickly than others, in the same way that some metals are more soluble in certain acids than others.

Bi-sulphide of carbon is open to two serious objections. In the first place its fumes have a very bad effect upon the workmen, and in the second place these fumes are probably more inflammable than the vapor of any other known liquid. I have known cases in my own experience where serious explosions have occurred, and consequent loss of life to the painters, from the use of paint in which bi-sulphide of carbon was used as a vehicle.

Mr. Custer.—As to steel tanks rusting more quickly than iron ones, a very pretty illustration of that came up at a large works in this city. They had been buying tank material rolled by a

mill which did not make a very good quality of iron, though good enough for this purpose. It did not have the appearance of good metal, but paint adhered to it well. For some reason they changed to steel made by one of the best manufacturers in the country. It was the finest looking steel I ever saw put into a tank. When punched, there was no sign of any scale breaking; but in two months after the paint was applied, it peeled and chipped off, and upon breaking the blisters, the rusted steel appeared underneath. It was finally concluded that there was a fine thin scale on this particular steel, and laborious scraping was done to remove what was apparently not there.

The point I wish to make in this is that after this laborious scraping had been done, and the steel thoroughly cleaned, there was no difficulty whatever in painting the surface, and the paint is in good condition, as far as is known at the present time.

If the surface of either iron or steel be thoroughly cleaned, the paint will protect the same and will prevent rusting. I do not think that an iron tank will last any longer than a steel tank, so far as rust is concerned, under the above conditions.

Mr. Livingston.—How is it that a tank filled with water will be affected quite differently from a tank filled with oil, so far as the tendency to rust on the exterior surface is concerned?

Mr. Custer.—That I cannot answer.

Mr. Livingston.—We know from experience that this is true.

Mr. Rinald.—As a vehicle, benzine would be unobjectionable if you could get a pigment which will represent all the properties of a paint, one that will form a thin film over the iron and protect it against any corroding influence. The benzine itself will not do any harm, because a good grade will evaporate altogether, leaving no residue on the iron. The same is true of bi-sulphide of carbon, which is very dangerous besides. It is liable to explode, and has an injurious effect on the lungs of those applying it.

Mr. Schumann.—The absolute removal of the scale should be insisted on. We use the sandblast in preference to the acid bath and find it very efficient. It does the work more quickly than the acid bath, and in riveted work all exposed surfaces can be readily reached. When the scale is removed, the paint seems to

flow more easily and to attach itself better to the surface of the metal. All specifications for iron work should contain a clause requiring the thorough cleaning of the metal before any paint is applied, and this should be followed up by good inspection.

Mr. Smith.—There is no doubt but that the cleaning of iron is a very important point, and if this is done by the use of the acid bath, unless the acid be properly applied and thoroughly removed afterward, it may leave the iron worse than before. The use of the sandblast in this connection is new to me; but it would seem to be a vast improvement, where it can be used economically, over the acid.

I would like to mention one or two additional points in regard to benzine as a vehicle. In the first place, the benzine is almost, though not quite, as dangerous, so far as liability to exploding and catching fire is concerned, as the bisulphide of carbon.

In the second place, the benzine on evaporating leaves a coating which is quite porous and not nearly as efficient as if some other vehicle were used in which the pigment was totally insoluble. In this case the paint depends on the elasticity and adhesiveness of the pigment itself, as the benzine is entirely volatile and leaves no binding material behind, other than that furnished by the pigment. As we have seen with vegetable gums which are soluble in alcohol, the film formed is not a good protection against exposure to the weather and, in general, it may be stated that a deposit from a solution is usually of a porous nature. This is shown very clearly in an electrolytic deposit of copper or other metal from a solution. Such a deposit is usually much more soluble in acids than the ordinary cast or wrought metal and requires careful burnishing before it presents a compact surface.

Mr. John L. Gill, Jr.—I would like to make a suggestion in regard to chimney stacks. Chimney stacks, made out of No. 14 iron, are very common on the Ohio and Mississippi river boats and they are usually painted with ordinary coal tar, a little lime being used to neutralize any acid. These stacks used to average about three years, not over three and a half years, before they would have to be entirely renewed. The first experience that I had with red lead for painting such stacks was on the steamboat "J. B. Williams," which was built

during the civil war. It has the original stacks on it to-day. When I was at Pittsburg, some two years ago, I saw the boat and was then informed that the present stacks were the ones placed on the boat at the time it was built. They had been painted simply with red lead and oil, inside and out, when the boat was built and then once a year afterwards. For that purpose red lead has proven itself the very best thing that I know of. For boiler fronts and that kind of work, I have never found anything equal to "Bessemer" paint.

Prof. E. V. Seeler (Visitor).—I would like to make an inquiry with respect to the iron work of buildings, whether the coats of paint as advocated would be worth the additional expense, or whether the red lead is not quite sufficient where the iron work is encased?

Mr. Smith.—In a building the paint is very liable to be brought in contact with moisture from the sweating of the iron after it is enclosed by the structure, and also from the mortar and cement used, which is almost invariably of alkaline character. This may affect the linseed oil vehicle more than exposure to weather. There are cases on record where iron beams taken out of masonry and painted with red lead have apparently been in an excellent state of preservation; but, as may be said of this whole subject of painting iron, it is very easy to pick out some particular instances which will apparently entirely disprove the experience had in a hundred other cases. By simply considering isolated cases, we cannot give due regard to the main problem.

Mr. H. C. Luders.—If it is absolutely necessary, in order that paint shall become a good protector, that the iron shall be thoroughly cleaned from mill-scale, then such treatment of the iron construction entering our large buildings should be insisted upon. It seems to me, however, that the removal of mill-scale will add very largely to the cost of the iron. Is there not some one present who could give us some information as to the practicability and the approximate cost of applying such treatment to the iron work in our large buildings?

Mr. Schumann.—I think it practicable to remove the mill-scale by means of the sandblast. The cost of sand-blasting would be about the same as that of the first coat of paint,

$1.50 per ton, to which the cost of handling the iron should be added.

Mr. A. Falkenau.—I would like to ask Mr. Schumann whether he would suggest having the sand-blasting done at the factory?

Mr. Schumann.—It would be desirable to do it at the mill where the material is manufactured.

Mr. Custer.—If the designers of modern buildings expected them to last only a few years, the question of first cost of the metal work would be a more serious one. Large buildings and bridges containing thousands of tons of iron are expected to last, however, long after their designers are in the grave. In such cases the question of cost should not be given too much weight. Even if the iron will cost a little more, if it can be perfectly protected, this should be done.

Mr. Schumann.—For the information of those who are not acquainted with the sand-blast apparatus of the present day, I would say that the motive power for the sand is compressed air. In former years steam was employed for this purpose.

The air is used under a pressure of 12 pounds per square inch, obtained with an ordinary air pump or compressor. The air is admitted from below and, passing through the sand, it takes along a certain amount of this through a rubber hose of any desired length. A man walks along with this rubber hose, to which a nozzle half an inch in diameter is attached, and directs it at will. If the large mills were to adopt this method, they would probably have to build a separate annex to their shops, in which the work could be placed and treated with the sandblast, for the sand would certainly be injurious to machinery.

A Member.—Would it not be better to have a temporary shed put up at the building site in which the iron could be treated with the sandblast?

Mr. Schumann.—I think that would give rise to some practical difficulties. It would mean considerable expense and I think it would be perfectly practicable to do the sand-blasting at the rolling mill.

XVIII.

NOTABLE ENGINEERING ACHIEVEMENTS IN THE GREAT LAKE REGION.*

By John Birkinbine, Active Member of the Club.

Read December 7, 1895.

A visitor to the great lakes who traverses the territory contiguous to them, must be impressed by the numerous evidences of engineering skill in all branches. The civil engineer shows his work in harbor improvements, docks, drainage systems and water supplies for cities and towns which develop so rapidly that those on the great lakes have increased their population over 500 per cent. in thirty years, some of them reaching 800 per cent. The architectural engineer has his record in tall and massive buildings sustained on treacherous ground by novel foundation methods. The network of tracks, the bridges, viaducts and tunnels connected with the great transportation systems which find termini at the lake cities, evidence the work of the railroad engineer. Similarly the immense fleet of 3,000 vessels, representing an aggregate of 1,300,000 tons (many of them of modern design fully up to the latest standards in construction and equipment), which float at elevations of from 573 to 602 feet above the ocean level, indicate what has been done by the marine engineer. Installations for light and power plants connected with towns, cities, industries and transportation, and also the application of electric light and power in mines, demonstrate that the electrical engineer, too, has been active on the great lakes. Mining engineering is prominent by exploitations in various kinds of earth and rock, made by steam shovels and supplied with aerial carriers, or carried to great depths and equipped with magnificent hoisting appliances, some of which are the finest examples of this class of work in the country. In each of these various divisions of

* The paper was illustrated by numerous lantern slides, among which were excellent flash-light views of underground work, taken by Professor Denton of the University of Minnesota.

engineering, of which a few specialties have been mentioned, the mechanical engineer had his part in designing and perfecting machinery of all classes, which does not suffer by comparison with others in different sections of the country.

Although there are five great lakes, the data herein refers to four only : namely, Lake Superior, Lake Michigan, Lake Huron and Lake Erie ; for although navigation between Lake Erie and Lake Ontario exists by the Welland Canal, the moderate depth in that canal, 12 to 14 feet, and the passage of twenty-five locks to overcome the difference in level of 325 feet, practically makes the business interest of the four great lakes named, largely independent of Lake Ontario.

One of the boldest engineering projects associated with the great lakes is the proposal to deepen and widen the summit level of the Welland Canal, dispensing with the "hydraulic staircase" of twenty-five locks, and substitute two pneumatic locks of 160 feet and 165 feet lift leading to the Niagara River below the Whirlpool rapids. Similar deepening of the canals on the St. Lawrence River and the introduction of other pneumatic locks are expected to give deep water navigation for the largest vessels between the St. Lawrence River at Montreal and Lake Erie, so that cargoes in bulk may thus pass from Duluth or Chicago into the Atlantic Ocean, and vice versa. But the project also includes a connection between the St. Lawrence River and Lake Champlain as well as between the latter and the Hudson River, supplied with pneumatic locks to give a similar outlet via New York City. Such an enterprise can only be made possible by the co-operation of the United States and Canadian governments upon a basis which insures reciprocity and permanent peace. For independently of the route being partly in Canadian and partly in United States territory, the diversion of a large volume of water from the St. Lawrence River into the Hudson River, demands the good offices of the two governments.

At present the bulk of the traffic of the great lakes does not reach Lake Ontario, and while recognizing the importance of its transportation and the progress of the cities adjacent to its shores, our immediate attention may properly be concentrated on the four lakes named above.

Of the thousands who annually stand enraptured before the Falls of Niagara, few consider that the volume of 275,000 cubic feet per second, falling 165 feet, represents the outlet of a chain of great lakes, giving magnificent inland water transportation between Buffalo, Chicago and Duluth, for 1,000 miles. Starting with the improvements at Niagara Falls, which have been referred to in other papers, we can merely glance hurriedly at a few of the engineering problems which present themselves in a visit to this great lake region.

The numerous large iron works and varied industries, together with the commodious elevators, enormous shipping and receiving docks located at Buffalo, Erie, Cleveland, Ashtabula, Sandusky, etc., on Lake Erie, offer, in their extent, the quantity of materials handled, and the labor-saving appliances used, a field for investigation. Erie, the shallowest of the lakes, is the only one whose bottom does not extend below the ocean level, but the fleet of vessels which traverses its waters, aggregates a tonnage exceeding 1¼ millions, and a value estimated at $70,000,000. Nowhere else in the country are large quantities of material handled cheaper or more rapidly than on Lake Erie, and the mechanical equipment of some of the docks, the special dumps for emptying coal cars bodily into vessels, the various swing derricks, etc., used to handle ore from vessels to the docks or cars, are marvelous in their way.

The shipbuilding interest of the lakes is full of information to an investigator; Cleveland, Detroit, Chicago, Superior, being prominent in this work. Many of the vessels lately constructed, especially to carry iron ore and coal, are magnificent specimens of marine architecture, equipped with triple expansion engines, and the latest addition to the passenger fleet have each a displacement of 4,500 tons, have quadruple expansion engines of 7,000 horse-power and twin screws. Another interesting specialty of the lake marine is the whaleback vessel, either equipped with steam-propelling machinery, or designed to act as a consort. These boats, novel in form, have apparently met the claims of the inventor, for fully forty are now in active use, with an aggregate at present available draught in the rivers connecting the great lakes, of 100,000 tons. During the past season of navigation, one steam whaleback towing two consorts, carried 132,000 gross tons of freight,

the fuel consumption being one-third of an ounce per ton mile. A late addition to the lake craft are steel canal boats, built of such size and strength as to withstand the lake storms, and yet capable of passing through the existing locks on the Erie Canal. These boats travel in groups, a propelling boat having attached to it three or four consorts. A feature of the shipbuilding on the lakes is the general practice of launching boats sideways, differing in this from that which prevails on the Atlantic seaboard; the lake shipbuilders claim that a vessel can in this way be placed in the water with less strain, and it certainly requires a smaller stream in front of the ways. The wooden sailing vessels, which two decades ago carried most of the freight on the great lakes, have been largely supplanted by steel vessels equipped with excellent machinery and constructed at prices which are claimed to discount the cost of European built ships of similar size. In no part of the nation has there been greater activity than in the ship-building works and dry docks of the great lakes, and in no part of our land is the proportion of American built and American owned vessels so great, yet this magnificent trade can be easily crippled in case of any dispute which would result in open rupture between the Dominion of Canada and the United States.

Continuing the journey across Lake Erie, we reach the Detroit River (where greater traffic passes than at any other point in the country), and thence through the comparatively shallow waters of Lake St. Clair and the St. Clair River, where an important engineering structure is crossed, namely the St. Clair tunnel. The engineer has here constructed at a cost of nearly three million dollars a metal tube 19 feet 10 inches in diameter below the bed of the stream, for a distance of 6,025 feet, and built approaches on the opposite shores aggregating 5,603 feet in length. By this work through rail connection is maintained between the Grand Trunk Railway terminus at Sarnia, Canada, and the Chicago and Grand Trunk Railway at Port Huron, Michigan.

The extensive lumber and salt industries of the lower portion of Lake Huron, and the Straits of Mackinaw, which connect its upper portion with Lake Michigan, next present features of interest to the engineer; in the improved machinery and the well-drill-

ing appliances in the South and the magnificent ice breakers which carry trains of cars across the straits, so as to maintain communication in the winter in the North. The latest of these, the "Ste. Marie," is a powerful steam vessel, 300 feet long, weighing some 3,000 tons, with engines of 4,500 horse-power and 14-foot propellors at either end, which permit it to make its way through ice nearly two feet thick, at the rate of eight miles per hour.

In passing through Lakes Huron or Michigan to Lake Superior, the Government work in the improvement of the Hay Lake channel, attracts attention, but greater interest is centered at Sault. Ste. Marie, the name borne by two towns on opposite sides of the St. Mary's River, one in Canada and one in the United States, between which Lake Superior empties itself, at the rate of 90,000 cubic feet per second in a series of rapids about one mile in length. On the American side are two locks for overcoming the difference in level of 18 feet. One of these, constructed in 1880, is 515 feet long, 80 feet wide, narrowed to 60 feet at the gates. The other, just approaching completion, is 800 feet long and 100 feet wide throughout. This latter is built on the site occupied by the two original locks erected in 1856, whose length was 350 feet, width 70 feet, and depth at miter sills but 12 feet. Each lock had a lift of 9 feet. On the Canadian side a lock 900 feet long and 60 feet wide was opened for traffic in September, 1895.

When the first pair of locks was proposed, progressive men of forty years ago considered the dimensions larger than would be required in a century. In 1881 they were supplanted by the present lock, and during 1895 this 515 feet by 80 feet lock, in less than eight months passed 16,793 vessels, carrying over fourteen million tons of freight, while during the season of navigation there was a continual congestion in the canal which detained vessels on an average of eight or ten hours each. In September the new Canadian canal was opened for traffic and partially relieved this congestion by passing in three months 1,163 vessels, which added some 600,000 tons to the Lake Superior business, bringing the total to fifteen million tons of freight passing both locks. In 1894 the traffic through the St. Mary's ship canal in tons multi-

plied by the distance traveled by the carriers was nearly eleven billion ton miles, and the average cost of carrying freight was one mill per ton mile.

The large new American lock (a view of which, before completion, is shown on Plate I) is expected to augment the volume of business next year, and reduce delays to a minimum. When the dimensions of this lock, or even of the one now in use, are compared with those with which we are familiar on our rivers, their immensity can be appreciated, and the demand upon the facilities available during the past year will appear from the statement that in 231 days that the American Canal was open for navigation, 7,039 lockages were made; that is, this lock, 515 feet by 80 feet, was filled and emptied 30½ times per day for the entire season. Each lockage (omitting displacement of vessels) requires over five million gallons of water. The new American lock will demand about eleven million gallons. The weight of one leaf of the lower gate of the large lock is 175 tons. From a paper presented before the Michigan Engineering Society by J. L. Collard, Assistant Engineer in charge, the following data concerning the masonry construction of the new lock is excerpted. The cofferdam, which was commenced in 1887, enclosed an area of about 1500 feet by 300 feet and cost

For dredging by the hour	$59,044 50
2,635,847 feet B. M. timber	37,428 92
Framing building and fitting cribs	14,982 22
662,410 pounds iron drift bolts	1,651 23
64,424 cubic yards clay	36,077 56
Total	$149,184 43

Excavations for the site of lock were begun in April, 1889, and finished in August, 1891.

130,085 cubic yards of earth were removed at cost of	$ 55,936 55
106,602 " " rock " " "	141,780 66
Total	$197,717 21

The work of constructing the masonry began in the latter part of June, 1891. The lock walls rest on concrete foundations made of one part Milwaukee natural cement, one and a half parts sand, and four parts broken stone. These foundations are laid on a line

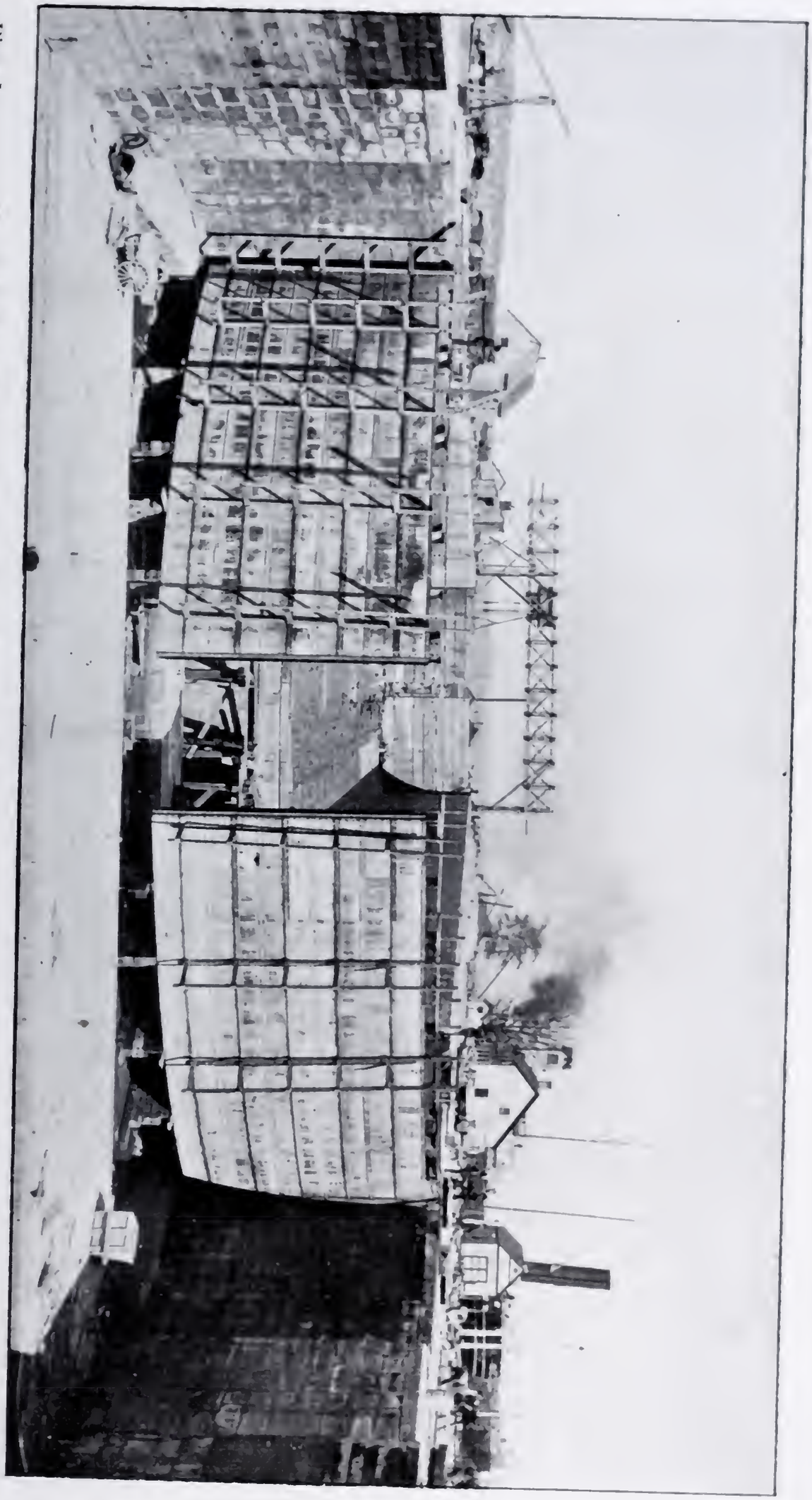


Plate I. The 800 Feet by 100 Feet Lock at Sault Ste Marie, Michigan, Approaching Completion.

three feet out from the face of the masonry wall and average two feet in thickness, 1.352 barrels of cement being used per cubic yard of concrete. 18,741 cubic yards of cut stone were laid, requiring an average of 0.292 barrel per cubic yard, the mortar being composed of one part Portland cement and one part sand. All the cut stone amounted to 14,278 pieces, of which about 10,000 were of uniform size, viz., 6 x 3 x 2 feet. The largest stones when cut contained 105.25 cubic feet and weighed 8.28 tons. The stone, which was limestone from Kelley Island in Lake Erie, weighed 156.23 pounds per cubic foot, and the ultimate crushing strength determined from a number of 3-inch cubes was 12,177 pounds per square inch. The lock walls are each 1,100 feet long and from 43 feet 6 inches to 45 feet high ; they are 20 feet wide at the bottom, 10 feet wide at the top, the ends of the walls being 36 feet wide from base to top.

The total masonry laid was 80,876.61 cubic yards. There were used for laying masonry 68,935 barrels of cement, an average of 0.778 barrels per cubic yard of masonry. Of the total masonry laid 59.7 per cent. was backing stone, 23.1 per cent. cut stone, and 17.2 per cent. mortar. The cost to the United States of the masonry of the 800 feet lock was for

Laying 10,522 cubic yards concrete at $4.50 per cubic yard	$ 47,349 00
Furnishing 18,741.04 cubic yards of cut stone at $26.00	487,267 04
Laying 18,741.04 cubic yards cut stone at $2.50	46,852 60
Furnishing 44,515.25 cubic yards backing stone at $6.00	267,079 50
Laying 48,276.04 cubic yards* backing stone at $2.50	120,690 10
Furnishing 7,650 barrels Portland cement at $3.00 per barrel	22,950 00
Furnishing 71,755 barrels of natural cement at $1.30	93,281 50
Total	$1,085,469 74

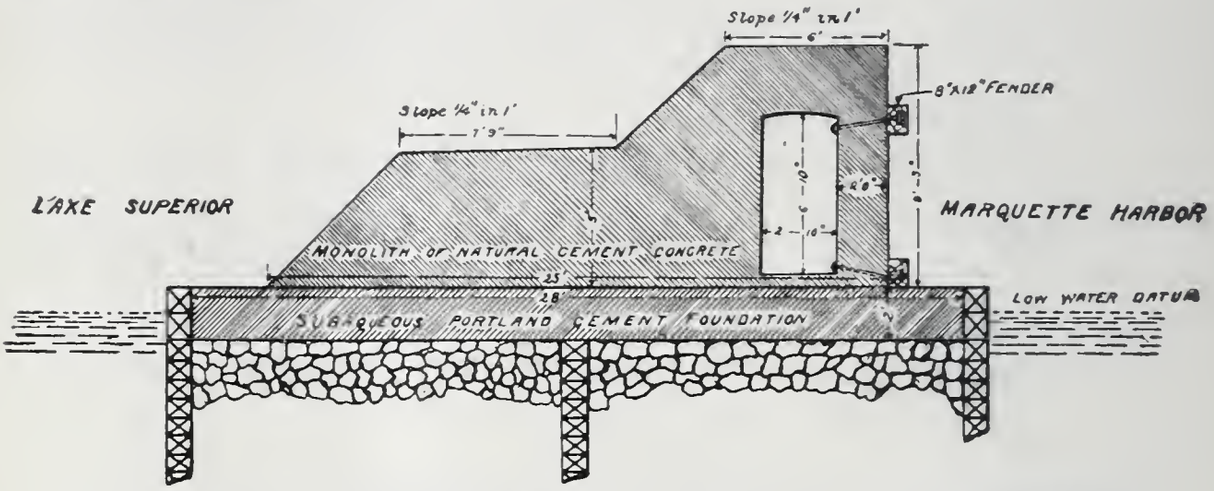
* In this was included stone taken from the old abandoned locks which were constructed in 1853–1855, at a cost of one million dollars for canal and locks.

Over half a million pounds of castings were used for anchorages, for the gates, etc., costing $20,477.64.

The total cost of the completed lock with its steel gates, hydraulic mechanism, etc., is not yet accessible.

The great inland sea of Lake Superior, with its water surface of 32,000 square miles, and its length between extremes of 390 miles, offers many wonderful examples of engineering skill.

Beside the Government works at Sault Ste. Marie and improvements to various harbors, special interest attaches to the breakwater now being constructed at Marquette and to the artificial entrance to the Duluth harbor. The former is of monolithic construction, a series of beton blocks being molded in place, each block weighing about 100 tons. The blocks are ten feet in length and have a cross-section shown in diagram, viz., breadth of foundation 28 feet, average thickness 2 feet, width of base of monolithic section 23 feet, maximum height 9 feet 3 inches. In construction the monoliths were built with alternate spaces, which were subsequently filled by similar monoliths, a joint of tarred paper being placed between each ten-foot section. This was done



CROSS SECTION OF CONCRETE SUPERSTRUCTURE OF BREAKWATER
MARQUETTE MICHIGAN

to provide for local settlement, affecting but a small portion of the breakwater, which has a total length of 3,000 feet. Mr. Clarence Coleman, C.E., engineer in charge of the work, states that for the subaqueous work, two feet thick, which rests upon the old breakwater cribbing, Portland cement was used; but the monolithic blocks are made from natural cement, local water-washed sand and quartzite, the latter being broken to from $1\frac{1}{2}$ inches to 2 inches. In molding each ten-foot section, the passage way shown, 6 feet 10 inches by 2 feet 10 inches, is formed, so that when the work is completed the lighthouse tender can in stormy weather use this (which is continuous for 3,000 feet) to reach the light at the outer end of the breakwater.

The Duluth entry is of interest because it was cut through Minnesota point (a sand spit which incloses the harbor), against

the advice of parties skilled in harbor work, but has maintained itself, and has not been the cause of deterioration to other parts of the harbor, as was expected.

The five iron ore ranges and the copper range, which have added so much to the appreciation of the territory tributary to Lake Superior, the silver exploitation on the north and south shores and on Silver Islet, the gold mining in upper Michigan, in Minnesota and Canada, and the stone quarries, all present features of interest to the engineer. The extent of these mining operations may be gauged from the fact that within forty years 100,000,000 gross tons of iron ore, and nearly the same amount of rock containing from 0.7 to 3.5 per cent of copper (for the ingot copper from this amounts to 800,000 tons), have been taken from the earth, and some of the workings have reached a depth of nearly one mile from the surface. The mining methods employed, the improved systems of timbering, in some cases the hoisting and pumping equipment, are worthy of study and imitation.

Three instances of machinery employed are offered. The elaborate equipment of the Calumet and Hecla copper mines includes a pair of quadruple expansion hoisting engines, each with steam cylinders 18 inches, 27¾ inches, 48 inches and 90 inches in diameter, giving motion to conical drums from 14 feet to 24 feet in diameter and 12 feet face, whose revolutions lift cages loaded with six tons of ore at the speed of fast railway travel, from depths of 4,000 feet and more below the surface. It is worthy of remark that this machinery is of Philadelphia manufacture.

At the Tamarack mine, thirty-nine cars per hour were raised from a depth of 3,186 feet for six consecutive hours. This is equivalent to an average hoisting speed of 3,180 feet per minute, or 36.1 miles an hour, allowing a trifle over one minute for loading and unloading the cages. The load of rock was 6,720 pounds. This work was performed with a direct-acting hoisting engine, with steam cylinders 42 x 84 inches, and the hoisting drum 30 feet in diameter. At another shaft owned by the Tamarack Mining Company, a trip was made from a depth of 4,500 feet in one and one-quarter minute, equivalent to a speed of nearly 41 miles an hour. At this shaft the engine is 32 x 84 inches, and the hoisting drum, a double cone, 13½ feet and 36 feet diameter;

each cone will carry 6,000 feet of rope. For short periods speeds as high as 4,200 feet per minute have been observed.

At the Chapia iron ore mine, in the Menominee range, a vertical compound pumping engine, with cylinders, 50 and 100 inches in diameter and 10 feet stroke, is designed to deliver 3,000 gallons per minute from a depth of 1,500 feet. The plunger pumps, 28 inches in diameter and 10 feet stroke, are connected to the engine through a horizontal beam, and also to a 40-foot fly-wheel, weighing 160 tons. At this mine the entire power equipment is arranged to work either with steam or with compressed air, the latter being developed by a waterfall three miles distant, and conveyed to the mine in 30-inch wrought iron pipes.

As illustrating the depths reached by some of the mining operations of Lake Superior and the relations which the mouth and bottom of various shafts bear to the level of the ocean and that of Lake Superior, it may be stated that in the copper region the work has been carried to a depth of nearly one mile from the surface, and those interested in these exploitations anticipate no unsurmountable difficulties in reaching depths of 10,000 feet. The surface at these mines approximates 650 feet above Lake Superior or 1,250 feet above sea level, but the vertical shafts of the Tamarack and Calumet and Hecla, the slopes of the Quincy and other mines, extend far below the water level of Lake Superior and of the ocean, and the Silver Islet workings were carried from a few feet above the lake level to below ocean level.

The iron mines are located from 550 to 1,200 feet above lake level, and although a number have been exploited to or below lake level, but a few have been carried to depths below ocean level. The high temperatures experienced in the Comstock lode and other deep workings in the Western States, is not apparent in the Lake Superior mines, which have penetrated the earth for great distances. The increase in temperature is not great, and at 1,500 feet the mine water becomes saline, but as greater depths are reached more objectionable characteristics are noticed, the water becoming so acrid as to destroy books and clothing and affect the skin.

The equipments for mining and handling iron ore are such that in some cases the mineral is never touched by hand until it

is being shoveled into buckets in the holds of vessels at the lower lake ports; this applies especially to steam-shovel mining, and to a minor extent to "milling" operations. But even where the ore is dug by hand, appliances for transferring it from mine cars to railway cars through pockets, and from railway cars into vessels by means of expensive docks fitted with hundreds of pockets, each connected with a spout, which can be let down into the hold of the vessel, permit cheap and rapid handling, and reduce the labor cost to a minimum.

In some of the iron ore mines ore is dug from 500 to 700 feet below the surface and delivered on cars for shipment for less than 70 cents per ton. This includes wages of miners, cost of light, explosives, timbering, etc., surface and machinery attendance, repairs and all charges except royalty, general administration, and interest on investment.

Instances of economic mining are numerous, but it is questionable if any record exceeds that of the Atlantic Copper Company, mining rock which in late years has yielded but $\frac{3}{4}$ per cent. of copper from depths of from 1,500 to 2,000 feet. At 10 cents per pound of ingot copper this would represent an income of $1.70 per ton of rock mined, sorted, crushed, passed through steam stamps, jigs and over slime tables, the concentrate being shipped to a refining plant; and yet with ore as lean as the tailings from some other copper mines, this plant has paid satisfactory dividends.

During the business depression which has characterized the past two years, millions of tons of iron ore have been mined in the Lake Superior region, shipped by railroad from 15 to 90 miles to ore docks, transferred to vessels, and carried from 600 to 1,000 miles, unloaded and delivered on cars at lower lake ports for from $2.00 to $3.00 per ton. Although little if any profit (after paying royalties or interest) resulted from these low prices, the possibility of accomplishing the above result is a tribute to the skill in mining, transporting and handling large quantities of ore.

The shipment of mineral from the Lake Superior district has encouraged the construction of nearly if not quite one thousand miles of railroad, a score of shipping docks, and numerous

vessels of improved design. The iron ore shipping docks alone have required an outlay of about $5,000,000, the cost averaging about $1,000 per pocket, or from $8.00 to $10.00 per gross ton capacity. Some of the docks demanded 10,000,000 feet B. M. of lumber in their construction. The method of construction followed in the erection of these iron ore docks is well illustrated by Plate II, the drawing for which was kindly furnished by Mr. R. Angst, C. E., and copied for the PROCEEDINGS by Mr. Harrison Souder, C. E. A perspective view of the ore-shipping dock at Two Harbors, Minn., is shown on Plate III.

The structures, made of timber, framed and braced, are carried on piles and must sustain the weight of ore in the pockets as well as that of loaded trains on the dock, withstand moderate wave and wind forces, etc.

The transverse view shows a section across a dock, one pocket opening on the left side, and one on the right side, the openings are closed by swing doors which, when open, permit the ore to slide down steel chutes, which are lowered into the vessel holds. The chute, which weighs about 2,500 pounds, is partly shown at the right-hand pocket. The elevation shows the interior of one pocket and parts of the framing inclosing others on either side.

Large investments in the receiving docks of lower lake ports supplement the shipping docks and permit of low cost and quick dispatch, as is well exhibited by the new steamer "Victory," the largest of the lake marine, which was loaded with iron ore at Two Harbors in five hours, and discharged a cargo of 3,650 tons into railroad cars at Ashtabula in six hours thirty minutes, working eleven hatches simultaneously. At the same port this vessel was loaded with 4,000 tons of coal, by the car-dumping machine, in ten hours, fifteen hours being required at the head of the lakes to remove the cargo. A vessel of modern construction can go from Lake Erie ports to the head of Lake Superior light, receive a cargo, return and discharge its load in seven days; but if loaded with coal going west, the average round trip, including two loadings and two discharges, occupies nine to ten days.

The construction of these ore and coal shipping and receiving docks, grain elevators, gauged by millions of bushels, flour mills whose daily product exceeds 5,000 barrels, saw mills which

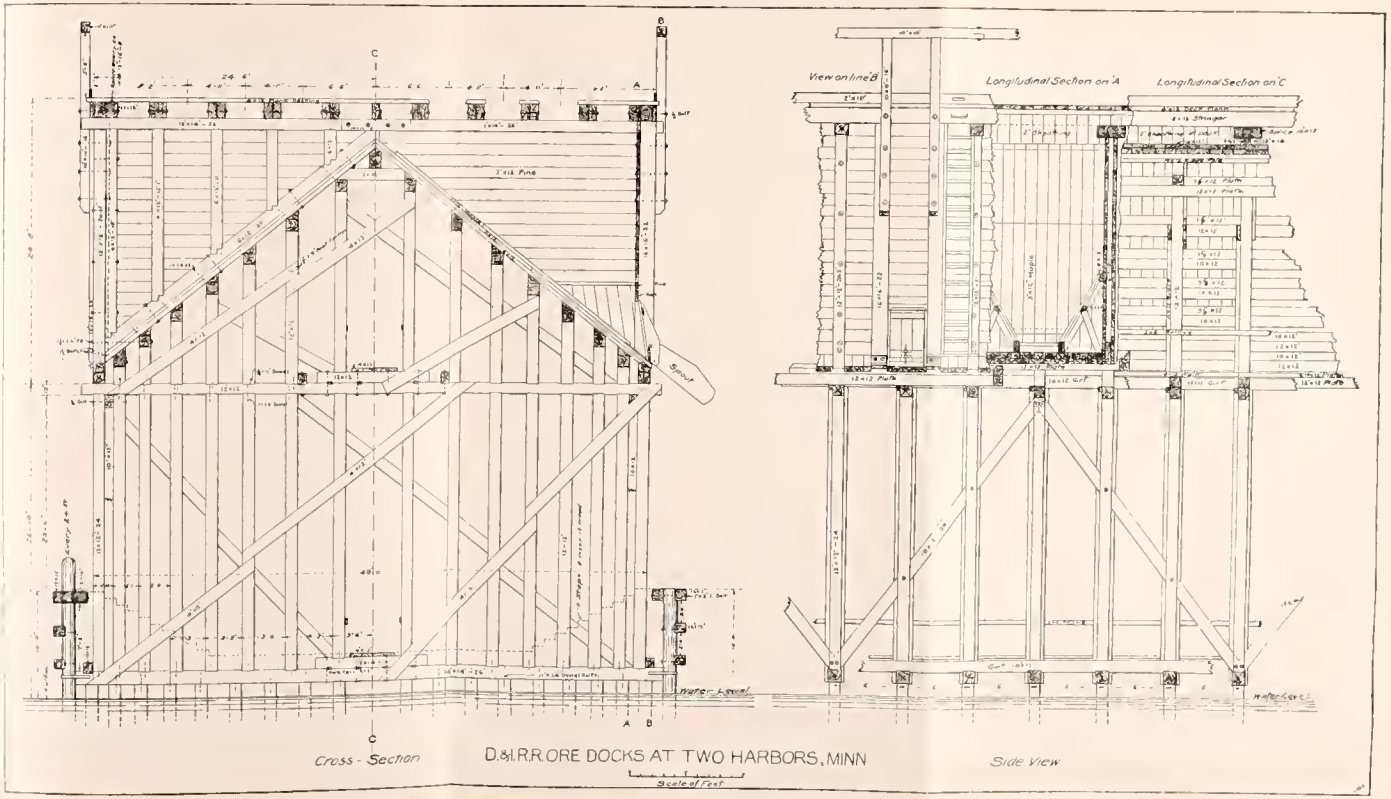
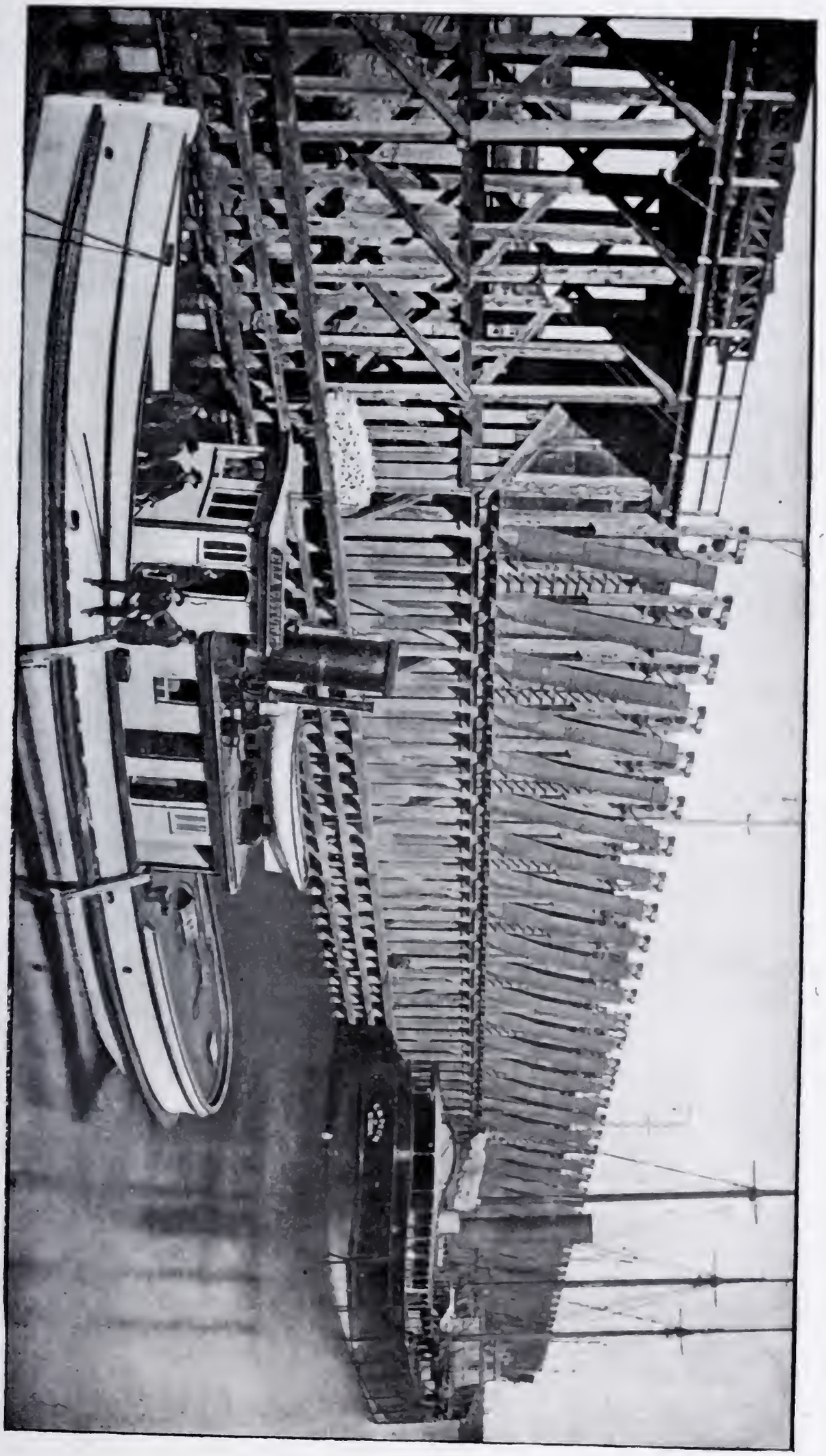

Cross-Section
D.&I.R.R. ORE DOCKS AT TWO HARBORS, MINN
Side View
Scale of Feet
View on line B
Longitudinal Section on A
Longitudinal Section on C
Water Level
Spout

Plate II.

Plate III.



Ore-Shipping Dock at Two Harbors, Minn.

handle millions of feet of lumber in a month, the railroads leading to the mines, which are well constructed and equipped with heavy locomotives, drop bottom cars with automatic couplers and air brakes, all show that the engineer has been a factor in the development of this country.

The water powers of Lake Superior should receive some attention, as interest in these is likely to increase. The immense volume passing through the St. Mary's River has but a moderate fall, and a canal to utilize part of this is in course of construction, but Lake Superior is surrounded by a rim of hills approaching the shore so closely as to produce a series of available falls at a number of places. The accessible power which seems to be the largest, as far as my investigation has shown, is that at the head of Lake Superior, where the St. Louis River, draining the area back of this rim of hills of nearly 4,000 square miles, breaks through within ten miles of the head of navigation, and has a fall of nearly 500 feet. This power, controlled principally by Philadelphia capital, was the subject of two reports, the preparation of which assisted materially in appreciating the importance of the great lakes.

Without claiming to have even mentioned all of the prominent engineering works tributary to Lakes Superior, Huron and Erie, further reference to these must be omitted to briefly refer to the numerous evidences of the engineer's skill on Lake Michigan.

Milwaukee or Chicago alone present many elaborate designs and constructions which must be passed by and reference will be confined to one special feature connected with each city.

For Milwaukee is selected the propeller pump which was constructed in that city, to flush the Milwaukee River by adding to one of its branches a volume of 40,000 cubic feet per minute from the lake by means of a tunnel one-half a mile long, the lift being about 4 feet A 4-bladed propeller 14 feet in diameter, driven direct by a vertical compound engine, is reported to have developed a duty of 76,000,000 feet pounds per 100 pounds of coal, or 102,000,000 feet pounds per 100 pounds of steam used.

The drainage canal at Chicago, however, is the great work now in progress in the territory tributary to Lake Michigan. It is a channel 34 miles long, 160 feet wide at the bottom, and 22 to 26 feet in depth, requiring 40,000,000 cubic yards of excavation, of

which about one-third is cut through limestone rock. The Chicago drainage channel has a greater cross-section than any of the large canals of the world, and on it powerful machinery for digging and hoisting, steam shovels, excavators, inclines, conveyors, derricks, cantilevers, cableways, channellers, power drills, pumps, etc., multiply the effective productiveness of human labor. Machinery does the hardest work of digging and shoveling and horse-power was used in removing the top soil, more than 1,000 horses and mules being thus employed. The view given on Plate IV, shows one of the rock cuttings, with cantilever hoists for conveying the excavated material to the spoil bank.

The men work by the hour and there are great numbers of laborers resting and others take the vacant places in a sort of rotation, which requires as much as a three-fold number of men from whom to fill the needed average working-force for each day.

But an army of workmen are necessary for an enterprise of this magnitude; for as men may stop work at any time, get their wages, and after spending them go to work again on some of the twenty-nine sections of the drainage channel, the number of those who work but part of the time is so large that, especially after pay-day, it is difficult to wake up a full working force in the channel.

Mr. Joseph Gruenhut, labor statistician, states that "the wages of one full working day of 8,245 men amounted to $14,150, being an average of $1.71 per man per day.

Those working by the day received the following: 6,124 men at $1.50, 10 at $1.60, 30 at $1.65, 603 at $1.75, 354 at $2.00, 43 at $2.25, 100 at $2.50, 86 at $2.75, 286 at $3.00, 12 at $3.25, 45 at $3.50, 30 at $4.00, 4 at $4.50, and 50 boys at 75 cents.

Those paid by the month received at the following monthly rates: 40 men at $50, 10 at $55, 76 at $60, 8 at $65, 7 at $70, 95 at $75, 11 at $80, 11 at $85, 70 at $90, 2 at $95, 40 at $100, 1 at $110, 3 at $115, 80 at $125, 1 at $130, 1 at $140, 3 at $150, 1 at $350.

The employees each pay 50 cents a month to a hospital fund, for which they receive medical attendance in case of sickness and accidents.

Board in the camps is from $4 to $4.50 per week. About two-

Spoil bank. Cantilevers. First, second and third benches of rock cutting.

Plate IV.

View of Rock Cutting, Chicago Drainage Channel.

thirds of all employed men, mostly single men, board in the camps. The married men live with their families in huts, cabins, tents and cottages along the channel, paying a nominal rent to the contractors who erected these frame houses for their working forces and collect about $5 a month rent from a family cottage, and 50 cents to $1 a month for each occupant of a dwelling used by men who board together in company so called.

Counting men, women and children, the population near the camps and dwellings in the neighboring villages, there are over 10,000 inhabitants in temporary frame dwellings.

There is a great difference in the proportion of mechanics to laborers on the earth and on the rock sections. Among 8,700 men there are more than 1,700 mechanics, foremen, clerks and superintendents earning $2.00 a day or more, while 7,000 men average $1.50 to $1.75 a day of ten hours. About one-third of the men work eleven hours on the night shift, getting an hour's extra pay as compared with the day shift. For every dollar paid to a skilled artisan and mechanic three dollars are paid out to mere physical strength of handy laborers and helpers, which indicates that it pays to work at skilled trades in connection with costly labor-aiding machinery."

Notwithstanding the forces employed and wages noted, the average prices paid contractors have been 76 cents per cubic yard for rock, 22 to 26 per cubic yard for dirt, figures only possible because of the machinery equipment. Channellers and power drills prepared the way for the use of large quantities of explosives, while steam shovels, tram cars, inclines, cableways, cantilevers, and swing derricks handled the material to spill banks.

The record of work shows that one man in ten hours can handle 4 to 5 cubic yards of rock into carts, 6 to 8 cubic yards into tram cars, and 8 to 10 cubic yards into cableways and cantilever buckets. The cableways cost to install about $12,000 and the cantilevers $28,000 each.

This paper has assumed proportions beyond what was intended, but it may truly be said, "the half has not been told" concerning a section of country about which there is progressive movement on every side.

The great iron and steel industry which has achieved renown

for its output and economies of production, the shops which turn out machinery magnificent in design and proportion, the varied manufactories, the bridge work, the municipal improvements, etc., have all been passed by in this imperfect chronicle, and yet a half-century ago but little of the territory included in this sketch was settled by the whites, with no railroads or steamboats adding to the means of communication, and with the exception of a few villages and trading posts, the upper lake region was a vast wilderness.

THE MINES AND PLANT OF THE EL CARMEN MINING COMPANY, VILLALDAMA, MEXICO.

By Harrison Souder, Active Member of the Club.

Read December 21, 1895.

In the spring of 1892, the Mexican Congress formulated a new mining code to regulate the location and development of all mineral lands. The new law defines the legal unit or "pertenencia" to be 100 meters square, which must be surveyed and properly monumented and recorded. It provides that a fee of $10 be paid for every "pertenencia" or hectare of land, when recorded; and also for an annual tax of $10. As a result of this law, many of the companies cut down their land holdings.

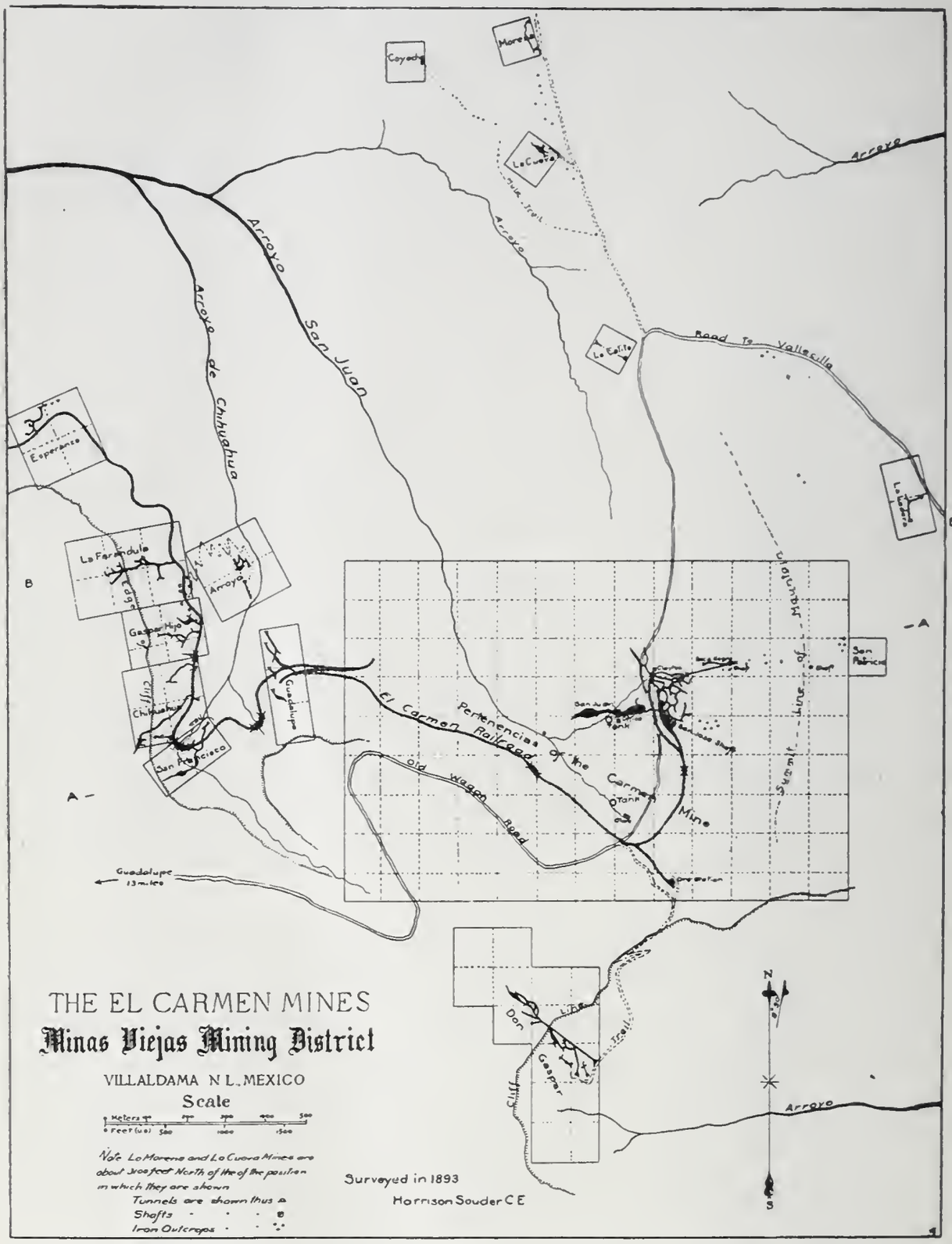
In August of 1892, the writer was requested by the El Carmen Mining Company to make surveys of their properties, and afterwards to superintend the reconstruction of the Company's railroad. In making the surveys, the underground workings were traversed and afterwards tied together by triangulation. A steel tape and a Gurley light mountain transit, with Saegmueller solar attachment, were used. The accompanying general map shows the relative location of the mines, the principal underground workings at time of survey, and about 3½ kilometers of railroad. A sectional elevation, on line *A-A* (see map), is shown separately.

The writer hopes that this paper may prove of some interest as a record of the difficulties encountered in this particular locality, and of the general methods employed in conducting large mining operations in a rugged country, where water is scarce. For much of the data in regard to the average cost of working the mines and railroad, and for the photographs, the writer is indebted to Mr. Casper S. Butcher, formerly President and Manager of the El Carmen Mining Company.

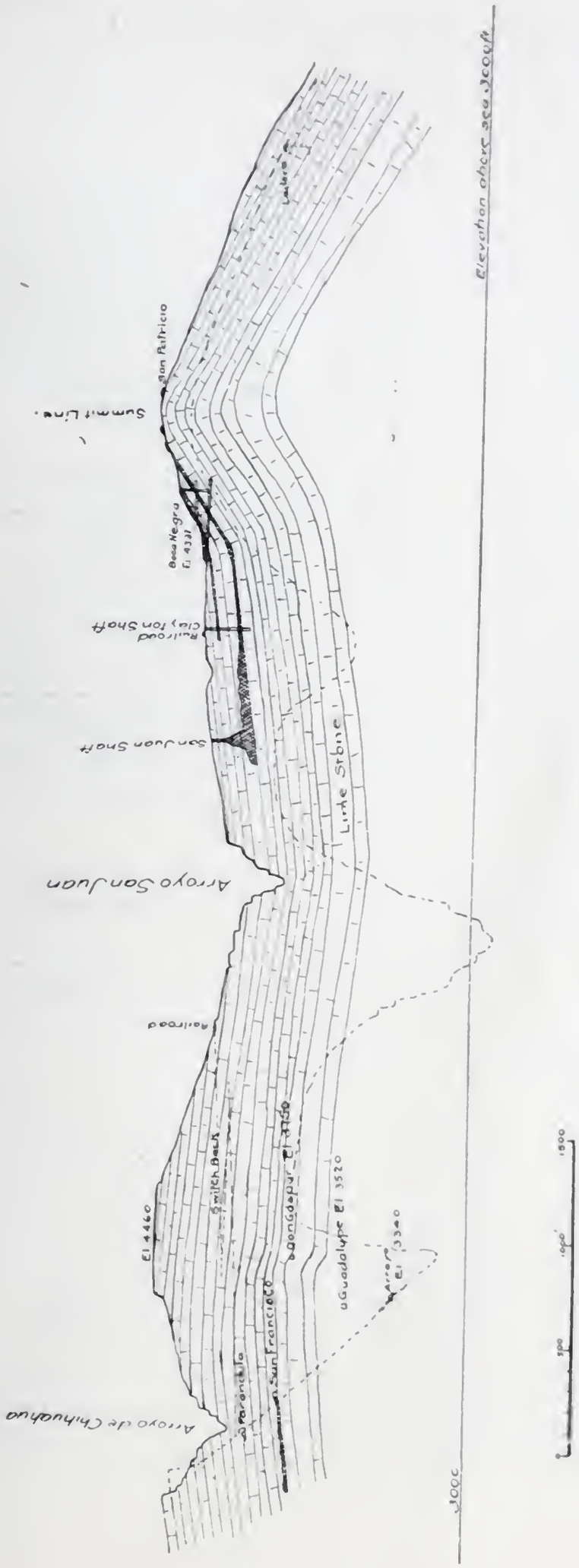
The Mines.

The El Carmen Mines are located in what is known locally as the "Mines Viejas" (old mines) district, in the Sierra de Yguana

ranges, jurisdiction of Villaldama, State of Neuvo Leon. These mines are owned and worked by the El Carmen Mining Company, formerly known as the Mexican Gaudalupe Mining



Company. A narrow-gage railroad, 14.5 miles long, operated by the Company, connects the mines with the Mexican National R. R. at Gaudalupe Station, which is about one mile north of



Section thro' Minas Viejas Mountain on Line A-A
Dotted Line Section on B-B

Villaldama Station, 110 miles south of Laredo, Texas, and 60 miles north of Monterey, to which latter place most of the ore is shipped. Mr. Persifor Fraser writes of the Yguana mountains:

"This range of mountains (which has an average height above the plains of about 3,000 feet and above the sea of over 4,000 feet) is composed exclusively of limestone, and throughout a great part of its extent shows signs of metamorphism. It is most frequently of a drab or bluish-drab color; breaks with a concoidal fracture and sharp, angular edges; and contains, very frequently, cavities filled with crystallized white calcite. This limestone has few of the characteristics which geologists are wont to associate with the Great Lower Silurean limestone of the United States, the one particular in which it resembles and even surpasses the latter being its enormous thickness, more than a mile. Prof. Heilprin thinks it beolngs to the Devonian or Carboniferous age."—*Trans. Amer. Soc. Mining Engineers, Vol. XII.*

Practically no fossils have been found in this district by which the age may be determined. The range is much broken by cañons, several thousand feet deep in many cases, the sides of which are almost sheer precipices. The formation is probably some 5,000 feet thick, and has a granite contact at the north and south ends, of which Mr. Fraser does not seem to have been aware. The limestone is known to the Mexicans as piedra azul, or blue stone, and its physical characteristics are very fairly described by Mr. Fraser. It lies in strata from 2 to 10 feet thick, and the layers appear to be sutured together.

The mines are at the apex of a great anticlinal fold of the limestone, and lie within about 500 feet of the summit of the range. The ore bodies, as a rule, seem to lie in beds, or better said, perhaps, in long narrow caves which expand and contract irregularly, and extend into the mountains many hundred feet, varying in height from a few inches to twenty-five feet at places. The general slope of the floor follows closely that of the bed of stratification of the limestone. The Mines Viejas, the principal mine and the oldest, and now known as the Carmen Mine, lies immediately adjoining the apex of the fold of the strata, though mostly on the west side. The ore body is the most extensive, and differs from the others in that it appears to be an immense double "manta," or blanket-vein, which follows the strata of lime; the two "mantas" being separated by nearly 100 feet of limestone. The upper bed is about 8 feet thick. It does not assay well, however, and has been abandoned. A large deposit

of black honey-combed iron and soft red iron ore, not carrying much lead or silver, forms part of the lower blanket, which is about 15 feet thick. Between these main beds are thin parallel veins of ferruginous material and calcite, which are practically barren.

The outlying mines or ore chambers, outcropping on the cliff across the gulch, seem to radiate from the Carmen deposit, and may possibly follow the lines of crevices which have been enlarged by the action of the water. The sides of the ore chambers show the action of the water, and many beautiful stalactite caverns are encountered. Above the ore body a stiff, heavy brown mud (lama) is sometimes found. In many cases this is absent, especially when hard iron ore, showing plainly the action of heat, is present. Much crystallized calc-spar is also found in streaks or as large boulders in the vein matter, which is made up of lead, iron and ferruginous disintegrated limestone. The ore averages nearly the same assay value in all the mines, with one or two exceptions. In some of the mines a body of rich lead carbonate is occasionally struck, and the assay for silver then runs higher. This body usually carries a thin core of galena or lead sulphide, and occasionally lead sulphate and small nuggets of ruby silver.

The output of these mines is an excellent fluxing ore, which is in demand for use in smelting with the refractory ores of Southern Mexico. The assay value of the ores from the different mines is given in the appended tables:

ASSAYS.—SEPTEMBER 26, 1892.

	Lead. %	Silver. ozs.	Iron. %	Silica. %
Sample from patio, two days	8.50	5.60	33.50	12.20
" seven cars, Farandula, two days	15.00	5.40	31.00	12.50
" two cars, Clayton, two days	5.00	2.00	44.00	7.60
" eighteen cars, Clayton (dump)	6.70	4.60	32.00	13.80
" 1,211 sacks, M. Viejas	7.20	4.50	39.00	6.00
" 668 sacks, Don Gaspar, second class	28.50	6.80	25.00	10.40
" two cars, San Francisco	10.00	5.00	37.50	14.20
" iron from Clayton	2.00	2.00	45.40	7.50
" special car from Clayton	3.20	2.30	43.20	6.40
Don Gaspar, first class, May, 1893	65.50	21.40		
Mines Viejas (1894)	12.00	3.00	32.00*	

* Excess over silica.

The mines are worked by manual labor. The pick and gad are used for the general run of ores which are soft; and double-handed drilling and blasting for the hard iron ores and the limestone. Two shifts a day are employed, each working nine hours The Carmen mine is worked from two shafts. The main or San José shaft is about 243 feet deep; the Clayton shaft, 185 feet deep, formerly in use, has been abandoned, and a new shaft has been sunk near Boca Negra. Ladder-ways give access to the mines and the men are not allowed to use the buckets.

The ore is carried to the shaft by peons, who are usually the younger men and boys, who place the sack of ore on their backs, holding it there by a strap or band passing around the sack and over their foreheads. It is hoisted in wooden buckets, holding about 600 pounds, by a two-mule whim and dumped into a small tram car, which is pushed by hand to the ore bins. From the bins it is loaded into the ore cars of the El Carmen Railroad.

The hoisting drum is 2 feet in diameter and the cable ½ inch. Two buckets are used, one being filled while the other is being hoisted, the round trip being made in 6 minutes and 45 seconds at the San José shaft. Considerable timbering is required in this mine, oak and cedar being used. The other mines require practically no timbering.

The following data indicate the rate of progress and the cost of tunneling: Drift 5 feet by 6½ feet, medium hard blue lime, double-handed drilling; two shifts of nine hours each; progress about one foot per day, at a cost of $3.75, Mexican currency. Don Gaspar Tunnel, in very hard lime, average progress 0.726 foot per day; cost by contract $7.00 per foot. Cost to the company before letting contract:

Two miners	$2.00
Two helpers	1.62½
One peon	.75
Drill boy	.30
Drills	.60
Powder	.45
Total	$5.72½

This is at the rate of $7.88 Mexican currency, or $3.94 U. S. currency, per foot. The company made several contracts at $4.00

and $5.00 per foot, supplying powder and steel. Dynamite was used in hard rock for the first blast, black powder for the others.

Where possible, small tram cars are used in the mines, with a track of 18-inch gage and a rail weighing 10 pounds per yard. Ore from the other mines is either carried to the cars on mules or burro back, or else, if the distance is not great, on the backs of peons. The mules carry from two to four sacks of ore, which average about 75 pounds, giving a load of about 300 pounds to a mule in good condition. The Don Gaspar ore, first class, averages 100 pounds to a sack. Two sacks to a mule is a load, as the trail is steep, and eighty sacks to one of the Company's cars. This ore is carried by mules. Don Gaspar, second class ore, is carried by contract for 2½ cents per sack, the distance packed being half a mile over a rough trail. Counting four sacks to a mule, thirty mules made five trips a day to the Ladera mine, distant 1½ miles, carrying a total of 22½ tons of ore. To tend and drive these mules required three men and a boy.

Sampling.

As each bucket of ore comes out of the shaft, a shovel full is taken out and thrown into a pile. This pile is quartered down and sampled every night and assayed the next day. The output of each mine is sampled in the same manner every day. Each small carload is also sampled, as the ore is dumped into the Mexican National cars, forming a rough check on the returns from the smelting company. This is also done to keep the percentage of iron in the low-grade ores above the minimum limit of 20.5 per cent. excess over silica. The ore is sorted at the mines into first and second class, the first comprising galena and high-grade lead carbonates. The low grade or regular ores are usually shipped in 10-carload lots, *i. e.*, a general sample of ten cars is made the basis of payment by the smelter. The laboratory outfit is very complete, comprising all the needed appliances and reagents for a complete chemical analysis and for wet or fire assays.

The Ventilation of the Mines.

The Carmen Mine is amply ventilated by means of its three shafts, which keep the air cool and fresh. The ventilation of the

outlying mines was and is a serious problem, and they will ultimately have to be abandoned, as the ore in some of them is not of sufficiently high grade to warrant expensive air shafts or fans. Only one shift a day could be worked in some of them, and then only after slaked lime had been scattered thickly over the walls and breasts, and the mines had been left idle for fourteen hours, when a candle would burn. The Don Gaspar Mine yields a higher grade ore, and a 28-inch fan was put up and air forced into the fronts through an 8-inch galvanized iron pipe with canvas joints. This was run about five hours a day and supplied air for fifteen men. Water and fuel had to be carried over on mules, and the engine likewise. The boiler was 20 horse-power, upright, about 10 feet high, and it took a force of eleven to twenty-five men nearly five days to get it down the trail to the mine, a distance of a half mile.

The trail is blasted out of the face of the cliff, and is both steep and narrow. Holes were drilled in the rock and iron bars were driven in these to serve as anchorage for the ropes used in lowering the boiler, which rested on a small truck with rollers running on heavy timbers laid along the trail.

An instance of natural ventilation was had in the Don Gaspar Mine, which like all those opening on the arroyos, is worked by tunnel. A crevice from $\frac{1}{4}$ inch to 1 inch wide and at right angles to the general direction of the tunnel was encountered about 250 feet from the mouth. Through this, at times, a strong draught of air blew and kept the air in the mines fairly pure.

Water Problem.

Water for general use and for the engines is pumped from the Villaldama River into an elevated wooden tank holding 22,000 gallons. The water is very hard, flowing, as it does, through a limestone region. In dry seasons a well must be sunk in the river bed to intercept the underflow, but during the rainy season the stream rises as much as 20 feet at times. Water is a luxury at the mines during the greater part of the year. Large tanks blasted out of the rock or built up of masonry and lined with cement collect rain water. These will hold about a month's supply for about 200 men and 150 animals, but the water is

generally stained red from the iron, and towards the end of the month, in dry weather, it becomes stagnant. Then water has to be hauled up in barrels on the train, and all that can be spared from the locomotive tank is taken. Iron tank cars, holding 1,000 gallons, are also used, a car being sent up about every other day. The tank is kept locked, and about two gallons of water a day is allowed each man. All the women, except five or six, are sent down the mountain during the dry season, these few being allowed to remain to manufacture "tortillas," the staple food of the Mexican. The scanty water supply is eked out with equarmiel or the unfermented juice of the "maguey," or century plant, a small quantity of which is collected on the mountain. Mescal and beer are the other beverages. Beans, tortillas, jerked beef and coffee form the miner's food. A Mexican miner can live on very little.

Labor is plentiful and good of its kind. The Mexicans are slow and deliberate in their movements, but are steady workers and quick to learn new methods. A Mexican was employed as general foreman in the mines who was very intelligent and efficient. The following are the prices for mine labor in this district in Mexican currency:

One general foreman (native), per month	$100.00
Mine foreman, per day	1 25
Barretero (miner), per day	1.00
Charqueador (assistant to miner), per day	0.81¼
Peons (packers), per day	0.50 to 0.75
Blacksmiths, from $50.00 to $70.00 per month.	

Mr. W. E. Butcher, Manager of the Providencia Mining Co. in the state of Guanajuato, furnished the writer the following prices for labor in that state for 1895. It is interesting to compare these with the wages paid in northern Mexico:

Miners, per day	$0.50
Other labor, per day	0.18 to 0.37
Blacksmiths, per day	0.75
Masons, per day	0.50 to 0.75
Boss Mason, per day	1.00
Carpenters, per day	0.50
Mexican mechanics, $1.50 to $3.00 per day.	

A Mexican dollar is worth about 50 cents in U. S. currency.

Interesting data in regard to the quality and cost of labor in Mexico were given in a paper by Mr. John Birkinbine, which appears in Vol. X, of the PROCEEDINGS of this Club.

The smelting plant, or "Hacienda," consisted of two 50-ton water-jacket furnaces, which were in operation about six months, but did not pay, and have since burnt down.

THE RAILROAD.

The El Carmen ores were originally hauled in wagons some 50 miles to Vallecillo, where they were smelted. Only the better grades could be touched. The present company spent from $15,000 to $18,000 in building an excellent wagon road down the east slope of the mountains to their furnaces at Guadalupe. But the heavy rains of the wet season washed it out badly in places, entailing great expense for maintenance. At times all the men at the mines had to be placed on road repair.

In 1885 the company decided to build a railroad as far as the "Mesa," a narrow plateau some 11 miles from the Hacienda at Guadalupe and about 1685 feet above it in elevation. It was at first deemed impossible to extend it beyond this point. The road starts from Guadalupe Station at an elevation above sea level of 1576 feet. A 30-inch gage was adopted to allow sharp curves. The first six kilometers are on an easy grade and have but two easy curves. The road then enters a narrow ravine in some low foot-hills. Getting over these foot-hills was a problem that required study, as the company did not wish to make any expensive cuts. The valley was narrow and did not allow much room for development. An ascending grade of 5 per cent. for 500 feet and a curve of 75 foot radius, with a summit cut of about 9 feet, was adopted. It is a very bad place, the trains often stalling there on the ascent, and it is the only place on the return trip where steam is required, except at the unloading station. The momentum of the train under full steam pressure is necessary to carry the loaded train over.

Reaching this summit, the road descends into a somewhat wider valley, on a $1\frac{1}{4}$ per cent. grade, 2400 feet long, and then enters a deep cañon, attaining at kilometer 13 an elevation of 850 feet above the starting point. Kilometer 13 is a water sta-

tion, a tank, lined with stone and cement, having been built here to catch the rainfall during the rainy season. A siding is laid here to hold a tank car in dry weather and to allow trains to pass each other. A short distance beyond, the track leaves the bottom of the cañon and begins the long and winding ascent, the grade varying from 4 to 5½ per cent. Many short bridges and culverts are required, as there are many small arroyos to be crossed.

The slope of this mountain side is about 35 degrees for some height, and above that towers the perpendicular front of the coursed limestone cliffs. Many large boulders lie in the cañon at the foot of the slope, and immense masses of rock are poised high up on the cliffs, apparently ready to fall. Sometimes these boulders, loosened by the storms, come down and play havoc with the track. At one or two places on this section, the curves and grades combined are almost too much for the train, which must be halted until the steam pressure is up to the full 150 pounds. At kilometer 18 is a comparatively level stretch called the "Mesa." A large tank has been blasted out of the rock and gathers in whatever rain falls on the mountain near by. At this point a siding is built to allow up and down trains to pass, and also for storing cars. Leaving the tank, a short tangent on a 6.6 per cent. grade is encountered, but by speeding the train before reaching it, it is easily overcome.

The "Mesa" was originally intended to be the terminus of the road, but as the three miles of wagon road between it and the mines were very difficult and expensive to maintain, it was decided to build the railroad, if possible to the mines. The outlook was not encouraging, as the cost for building on what was apparently the only possible route, was prohibitory. Upon a closer search, however, a cleft with perpendicular walls on either side was discovered in the mountains. The engineer, Mr. Butterworth, decided that it was feasible, and the work was undertaken. A number of trestle bridges were required, one 172 feet long and 27 feet high, several shorter ones, and one covered trestle at the head of a ravine, with a 76-foot radius of curvature, on a grade of 4.5 per cent., with a length of 134 feet and a height of 25 feet. Winding around the arroyos, on a continuous ascent, the track suddenly rounds a

sharp point of rock on a curve of 73-foot radius and enters the "Arroyo de la Palma," the cleft before mentioned. Here the road-bed is blasted from the face of the cliff. It is very narrow and one can lean from the engine and drop a coal down to a depth of about 150 feet without its grazing the face of the cliff. The work in this narrow gap was very heavy, being all blasted out of solid limestone. The view is very impressive, as may be seen from the accompanying illustration (Plate I). Massive boulders, weighing tons, are tumbled and scattered about as if some immense mine had been exploded. Several natural obelisks and a natural arch are among the formations. On the towering wall of rock, on the opposite side of the cleft, is a solitary Palmetto tree, the only one for miles around. From this the pass takes its name. Leaving the cliff, the track crosses a short trestle, plunges into a fearful mass of boulders, and then emerges at the other end of the pass on a 5.5 per cent. grade. A quarter of a mile farther "Buena Vista" is reached, so named by the Mexicans because of the magnificent view which can be enjoyed from this point. Candela Peak and Misa Cartujau, landmarks in this part of Mexico, are in plain view, as is also the town of Lampasoo, some fifty miles away, in clear weather. The track now follows the general contour of the mountain, here covered with a dense growth of scrub oak and mountain mahogany. On this section the curves are necessarily sharp, but the grades were purposely kept low so that the track would be on a level with the many mining tunnels in this part of the mountain. The only trestle of importance in this section is at the head of the "Arroyo de Chihuahua" at kilometer 22, with a radius of 87 feet on a grade of 4.8 per cent., a very severe combination, especially as the train usually has to stop on the trestle to drop a car at the loading station at this point. This trestle is shown in the illustration (Plate II), at the head of the horse-shoe curve. At several places the road-bed is built up on rock walls, the stone being laid dry and tied in with oak logs.

At kilometer 23, a very narrow sharp spur was encountered. At this point a double switch-back was introduced, a device which could probably have been used to advantage before, in overcoming the steep ascents. This arrangement resulted in a gain of

Plate I.—Trestle Bridge along the Precipice of the Arroyo de la Palma, Guadalupe R. R., Mexico.

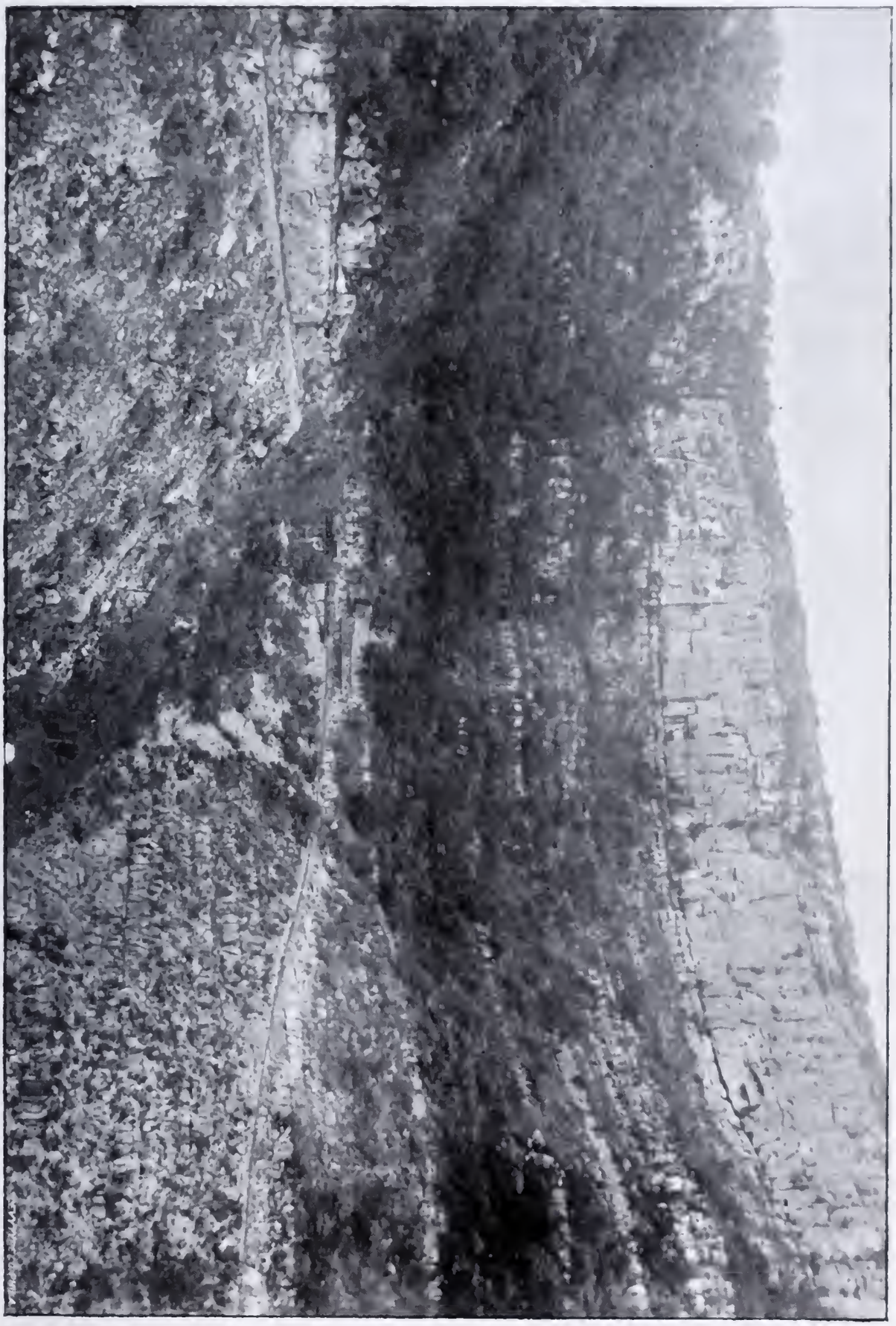


Plate II.—Arroyo de Chihuahua, Guadalupe R. R., Nuevo Leon, Mexico.

67.5 feet in elevation, by running about 1,600 feet and advancing horizontally 560 feet. At kilometer 24, is the terminus, with an elevation of 4,200 feet above sea-level, and 2,630 feet above Guadalupe station. Here the car chutes are built and switches and sidings are laid to the various shafts and tunnels.

The road-bed was made of the material at hand, generally earth, but in the bottom of the cañon from kilometer 9 to 12, is a stretch with as fine a natural stone ballast as could be desired. But little provision was made for draining the road-bed. The ties were originally 5 inches x 5 inches, sawed white pine sticks 6 feet long, and were renewed at the end of four or five years by ties of native oak, and occasionally of cedar and ash. These native ties formerly cost 33 cents a stick delivered, round, but lately 20 cents, hewn to a size 5 inches x 6 inches and 5 feet long. A 20-pound steel (English) rail was laid and proved much too light. The wheel flanges would strike the head of every bolt in the splice plates, until they were worn down. The rail head is so narrow that it soon wears the driving wheel tires out, and is itself rapidly worn away, especially at the very sharp curves on the trestles. The trestles were originally built of 6 inches x 6 inches timbers well braced and thoroughly bolted together. The total cost of the road was about $140,000 gold, an average of $9,600 per mile.

But little attention was given the road after it was built. When the writer took charge, it was in a most dilapidated state; four-fifths of the ties had rotted away entirely, excepting about an inch of hard shell at the surface, kept dry by the sun. Many of the spikes could be pulled out by hand. Some of the trestles were dangerously weak, with bolts out, timbers warped, and ties spaced from 2 to 4 feet apart. Guard-rails existed on only one trestle out of a total of twenty-eight. Spreading of the rails was a common occurrence and caused great loss of time. Several accidents would be allowed to take place on a trestle before it was repaired. In one case a car was derailed on a trestle, wrecking the latter as well as four loaded cars. The engine narrowly escaped and fortunately no lives were lost. It required two days to clear up the wreck and rebuilt the trestle. In accordance with the new plans, all trestles were supplied with 6 inches x 8 inches

and 6 inches x 10 inches double stringers, 8 inches x 8 inches posts, 6 inches x 8 inches ties, 6 feet long, spaced 8 inches apart, and 4 inches x 5 inches guard-rails. Bents were spaced 10 to 14 feet apart. Much trouble was experienced from creeping of the track down grade and jamming at the switches, which were of the stub type. It was necessary to cut off at the switch about an inch of rail every two months. This could have been remedied, but the necessary material was not at hand. The creeping of the rails was also very evident on the tangents, where the rails were often perceptibly bent.

A telephone line connected the mines with Gaudalupe, Villaldama, and the other stations. The poles were spaced originally about 235 feet apart, and afterwards about 185 feet. They cost originally about $1.00 and later 50 cents each delivered.

Rolling Stock.

The rolling stock consisted of two Porter locomotives, 24 ore cars, and one passenger car. Locomotive No. 1 has 4 drivers, 27½ inches in diameter, with a wheel base of 4 feet 8½ inches; total wheel base with pony truck 11 feet; cylinders 8 inches by 10 inches; total weight 21,000 pounds, with 16,000 pounds on the drivers. It has a saddle and rear tank, total capacity about 500 gallons, and carries about 1,700 pounds of coal.

Locomotive No. 2 has 4 drivers, 28 inches in diameter, with a wheel base of 4 feet 6 inches; total wheel base with pony truck 10 feet 11 inches; cylinders 9 inches by 14 inches; total weight 30,000 pounds, with 21,500 on the drivers; length over all 18 feet, width 6 feet. The weight of the four-wheel tender, empty, was about 2,700 pounds, and its capacity 600 gallons of water and one ton of coal. In addition, the locomotive had a saddle tank of a capacity of about 200 gallons.

The cost of these engines was about $3,000 each, f. o. b., Pittsburgh, Pa. The ore cars are of wrought iron and are side-dumping. They measure 7½ feet by 5½ feet, and are 2 feet deep inside, having a capacity of 82.5 cubic feet. The weight of the car is 3,460 pounds on a 4-foot wheel base. Their stated capacity is 10,000 pounds. The present price of these cars, f. o. b., Youngstown, Ohio, is $165. The company employed a regular force of

blacksmiths for repairing cars, and in 1893 began to build its own cars, using the sides of the old ones and a wooden body, thus making them much lighter.

Operation.

Each train made three trips daily in favorable weather, the first leaving about fifteen minutes before the second. Locomotive No. 2 pulled ten empty cars, No. 1 from four to five. In damp or rainy weather the rails became very slippery and only half the usual number of cars could then be pulled up, some being placed ahead of the locomotive, so that the train could be divided at difficult places.

The distance from Guadalupe to kilometer 13 was made in about 35 minutes, in dry weather. A stop was made here to oil the engine and take water, if necessary. About one hour was required to cover the next 11 kilometers. The return trip could be made in much less time, but, owing to the bad condition of the track, two hours was fixed as a minimum. Each train brought down from eight to fourteen loaded cars. The train crew consisted of an engineer, fireman and one brakeman for each car, all Mexicans except the engineer. The locomotive always went down last and backwards to keep the crown sheets covered with water, and by this arrangement the engineer could watch his train better.

Locomotive No. 1 usually consumed about 1000 pounds of coal and 600 gallons of water in making the round trip. Locomotive No. 2 required about 1400 pounds of coal and the same amount of water as No. 1.

In 1893–94 Pecos coal from the San Tomas mines, Texas, was used for the locomotives. Coal from the McAllister mines of Indian Territory was used for a time, but the engineer preferred the Pecos coal. The latter cost at that time $11.00 in Mexican currency, with exchange at $1.50, equal to $7.33 in United States currency, per ton delivered. The cost is now about $13.00 in Mexican money.

The following data are given in conclusion:

Average for Three Months, 1892.

[All values are given in Mexican currency. Exchange $1.50 Mexican currency equals $1.00 United States currency.]

Average number of tons hauled, to one car of the El Carmen R. R....	4.04
Tons shipped to one car of the Mexican National R. R.	14.26
Average cost, per ton, of hauling ore from mines to Gaudalupe, including all expenses of repair of cars and locomotives, tanks, track, road-bed, bridges and ore transportation.....	$1.044
Average cost per ton loading ore at Gaudalupe	0.134
Average cost per ton taking ore from old dump and o. b. El Carmen cars	0.408
Average cost per ton mining, including dead work in mines	4.400
Average cost per ton, all ore shipped o. b. cars, Mexican National R. R., every expense included	3.246
Average net price per ton received from smelter	4.913
Profit per ton.....	1.667

For One Month of 1893.

Average cost hauling ores, mines to Gaudalupe.....	$0.747
Average cost per ton loading ore at Gaudalupe	0.148
Average cost of mining per ton.....	2.682
Average cost of all regular ores o. b. Mexican National cars at Gaudalupe.....	2.743
Average net price per ton received from smelters for same.....	4.390
Profit per ton, regular ore	1.647
Average cost per ton, iron ores	1.390
Average net price received for iron ore	3.175
Profit per ton iron ore	1.785
Average per cent. deducted for moisture	10.900

NOTES AND COMMUNICATIONS.

ELECTRO-CHEMISTRY IN ITS PRACTICAL RELATIONS.

On December 14, 1895, Dr. Henry Leffmann and Mr. E. K. Landis, Active Members of the Club, gave an informal talk on Electro-Chemistry in its Practical Relations. The general nature of electrolysis was explained, and by means of the lantern decompositions of potassium iodid and sodium sulphate were shown. In the case of the latter substance, an infusion of purple cabbage was employed as an indicator, by which the liberated negative ion, SO_4, produced a red color, while the liberated positive ion, Na, produced, by secondary action, a green color.

As an illustration of the practical use of electrolysis, the Edison meter was shown in its practical form, and its operation briefly explained.

A form of electrical furnace was also exhibited, but not in operation.

Reference was made to a method of separating silver, when present in small amounts in copper ingots, enclosing the mass of copper in a canvas bag, and making it the anode of an electrical circuit. The whole of the copper is thus slowly removed before the silver is dissolved.

NOTES ON A BROKEN 48-INCH WATER MAIN.

At the meeting of December 21, 1895, Mr. A. J. Fuller, Active Member of the Club, exhibited lantern views showing a broken 48-inch water main. The following notes, relating thereto, have since been communicated:

The breaking of cast-iron water-pipe is frequently a very serious matter, and every precaution should be taken to avoid such accidents, particularly as they often involve the destruction of property and, in many instances, endanger the water-supply.

It is a well-known fact, to those experienced in such matters, that notwithstanding the great care taken to design pipes of sufficient strength, the thorough inspection to which they are subjected, and the careful handling and laying, there are frequently "breaks" and "splits" in water-pipes which occur oftener in new than in old lines, thus indicating that there is lacking some element of strength which careful investigation has so far failed to disclose.

Where breaks occur it is the exception to find flaws in the iron or any defect in the quality, the thickness, or in the concentric formation of the broken pipes that would be a positive reason for fractures, which in some instances occur under conditions that would seem to be impossible, as was recently demonstrated near the Spring Garden Water Works, when a pipe-casting which had formerly been used under a pressure of seventy-four (74) pounds broke under a pressure of thirty-six (36) pounds.

Pipes that have been tested at the foundry to 300 pounds have frequently broken under a pressure of from 20 to 45 pounds, and, in most cases, by "splitting" at either end, although at times a portion is broken entirely out at the ends, or at the center, and at any point in the circumference. In most instances of this character

it has been observed that the pipe-trench was in rock excavation, and since noticing this feature, concrete foundations, extending 2 or $2\frac{1}{2}$ feet back from the bells, have been placed under each pipe, when laid in rock excavations, with the result that there has since been a marked decrease in the number of broken mains.

The break at the Spring Garden Works, mentioned above, occurred about 400 feet from the engine-house, on the line of No. 5, 48-inch pumping main to the Queen Lane Reservoir, and at a point where a right-angle connection branches to connect with No. 11 main to the East Park Reservoir.

It had been of frequent occurrence to pump through the No. 5 main to the Queen Lane Reservoir, at an elevation of 218 feet, city datum, but at the time of the accident a 48-inch valve on this line, immediately beyond the connection to the No. 11 main, was closed, and the pumpage was, therefore, through the connection to the No. 11 main, and thence at an elevation of 133 feet, city datum, to the East Park Reservoir, a much less pressure than had frequently been used on this main.

The casting which broke was a 48 x 48 single branch, or "T." It was $1\frac{3}{8}$ inches thick in the barrel; the bells were 6 inches deep and weighed 810 pounds each, the total weight of the casting being 6,500 pounds. There were no ribs, nor any additional strengthening metal except where the arm joined the barrel, at which place the metal is $2\frac{1}{16}$ inches thick. The branch was set at an angle of about 22°, with the arm looking up. It was supported on a concrete foundation, with a strong backing of the same material opposite the arm. The pipes entering the three outlets of the branch were also supported upon concrete foundations.

The fracture of the casting was such that the entire upper half was removed by the force of the water, except at the bead end, where about 12 inches of the barrel remained projecting from the bell of the adjoining pipe. On one side of the arm, the fracture was directly in line with the "anchor bolt," but a few inches from the corresponding bolt on the opposite side. The iron was of good quality and the real cause of the break cannot be given.

The washout undermined 120 feet of an adjoining 30-inch main which fell of its own weight. Another 48-inch main was also endangered, but it fortunately was supported upon masonry piers and remained intact.

The Reading Railroad tracks, immediately below the break, were covered to a depth of 12 to 15 inches with dirt, and the pump-well of the No. 7 engine was partially and that of No. 11 completely filled with gravel. The force of the water washed a locomotive-tender from the track, and considerable other damage was done.

Fortunately, the system of pipe-connections at the Spring Garden Works is arranged so that it was necessary only to alter the stops to supply through other lines of pipe, but it is extremely desirable to prevent occurrences of this character, and, if possible, to obtain such light upon the subject that provision may be made to avoid them in future.

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, November 2, 1895.—President George S. Webster in the chair. Sixty-six members and visitors present.

Mr. George T. Gwilliam, Chairman of the Special Committee appointed for this purpose, presented a memorial of Clement Lodge, late Active Member of this Club.

Dr. Henry Leffmann read a paper on the "Water Supply of Rome." At the close of his remarks the speaker exhibited a series of lantern slides made principally from the illustrations in Vol. VIII. of *Parker's Archæology of Rome*, showing exterior views of the remains of some of the principal aqueducts, the shapes of cross-section of their channels, a map of Rome showing the courses by which they were brought to the city, etc.

Mr. George S. Webster, upon request, exhibited a number of photographic views of recent public work in bridges, sewers, etc., taken during construction and after completion, and plans of some important work projected and in progress.

Regular Meeting, November 16, 1895.—President George S. Webster in the chair. Seventy-three members and visitors present.

Mr. E. A. Custer read a paper, prepared jointly with Mr. F. P. Smith, on "Paint as a Protection for Iron."

At the close of the discussion, Mr. C. L. Prince exhibited a few lantern-slides, first in the lantern with the lime-light, and then in another with electric light, in order to show the comparative illuminating power of the two kinds of projection. The relative candle-power of the two lights was stated to be about as 1 to 3. The expense of obtaining an electric lantern for the Club was stated; but notwithstanding its superiority it seemed to be the sense of the meeting that its purchase was not advisable at the present time.

Business Meeting, December 7, 1895.—In the absence of the President the chair was occupied by the Vice-Presidents—first Mr. A. Falkenau, and afterward Mr. John L. Gill, Jr. There were eighty-four members and visitors present.

Nominations for officers for 1896 were duly made and seconded as follows:

Office.	*Nominee.*	*Proposer.*	*Seconder.*
President.	A. Falkenau.	Wm. J. Hoyt.	John C. Trautwine, Jr.
	F. H. Lewis.	W. C. Furber.	James Christie.
Vice-President.	Carl Hering.	James Christie.	Wm. R. Webster.
	Edw. K. Landis.	Edgar Marburg.	Harrison Souder.
	M. R. Mucklé, Jr.	Wm. J. Hoyt.	Geo. T. Gwilliam.
Secretary.	L. F. Rondinella.	John C. Trautwine, Jr.	W. C. Furber.
	E. R. Keller.	Rudolph Boericke.	Paul A. N. Winand.
Treasurer.	Geo. T. Gwilliam.	R. L. Humphrey.	Wm. J. Hoyt.

Directors.	W. C. Craumer.	C. H. Ott.	Wm. H. Robinson.
	Rudolph Boericke.	W. B. Riegner.	Wm. H. Robinson.
	Max Livingston.	John C. Trautwine, Jr.	James Christie.
	Wm. J. Hoyt.	C. L. Prince.	Wm. R. Webster.
	Jos. T. Richards.	W. C. Furber.	R. L. Humphrey.
	L. Y. Schermerhorn.	Henry Leffmann.	Geo. T. Gwilliam.
	Geo. B. Hartley.	John E. Codman.	John L. Gill, Jr.

The Tellers reported the following gentlemen elected to Active Membership: Messrs. William H. Adey, William D. Gharkey, F. L. Hand, Arthur Moorhead Hay, Daniel A. Hegarty, William A. Jones, Paul Foster Leach, Charles E. H. Sudler, Horace E. Newcomet, Howard C. Slater, Francis P. Smith, Thomas Smith, William C. Williamson and Francis P. Witmer, also Mr. C. W. Arny to Associate Membership.

The following resignations from Active Membership were read and duly accepted: Messrs. Howard Sellers, Pedro G. Salom, William C. H. Slagle, W. W. Stevens, Gaylord Thompson, George W. Irons, and J. Clarence Ogden.

Mr. John Birkinbine read a paper on "Notable Engineering Achievements in the Great Lake Region," illustrated by numerous lantern views.

Regular Meeting, December 21, 1895.—President George S. Webster in the chair. Forty-eight members and visitors present.

The Secretary announced that all nominees for office for 1896, as published in the last Record of Meeting, had accepted with the exceptions of Mr. M. R. Mucklé, Jr., for Vice-President and Mr. Edwin R. Keller for Secretary, whose declinations had been received.

Mr. Harrison Souder read a paper on "The Mines and Plant of the El Carmen Mining Co., Villaldama, Mexico," illustrated by lantern views.

Mr. Allen J. Fuller described and illustrated a break in a 48-inch water-main, which had recently occurred near the Spring Garden Pumping Station at Fairmount, Philadelphia.

Mr. Hermann S. Hering illustrated the difference in the horse-power necessary to operate trolley cars when they were run at regular time intervals, and when they were run so as to accommodate the varying travel at different parts of the day, showing the latter system to be the more economical of power.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, November 16, 1895.—Present: President George S. Webster, Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Edward K. Landis, Henry Leffmann, C. L. Prince, Wm. J. Hoyt, the Secretary and the Treasurer.

The Treasurer's Report for October showed:

Balance from September	$141 08	
Amount received during October	141 50	
		$282 58
Amount expended during October		90 00
Balance October 31st		$192 58

The Treasurer also reported that he had written to those members who were two years in arrears for dues, and read the form of letter and the replies received thereto. The Board decided to take no action in the case of these members, but instructed the Treasurer to notify them, with statement at the beginning of December, that in accordance with the second paragraph of Article VIII, Section 1, he would be obliged to drop them from the rolls if their indebtedness was not cancelled before the end of the year. Upon motion, the Treasurer was authorized to employ a collector for the backward accounts of Philadelphia members, at a compensation of 5 per cent. of his collections.

The Chairman of the Publication Committee, by letter, asked for instructions as to whether discounts should be given to news agencies on the sale of the Club's PROCEEDINGS, stating that past custom had been to allow no discount. Upon motion, the Committee was instructed to follow this precedent. The Publication Committee reported that the next number of the PROCEEDINGS would be issued in about one week.

Mr. E. K. Landis moved that in future the ballots for the election of new members contain, in addition to their present occupation, an abstract of their professional record, that members might be fully informed before voting. This motion was carried.

The Library Committee reported that they were continuing the work of having the Library put in shape gradually, that some volumes of periodicals had been bound, and that others had been selected and would be put in proper shape in a short time.

REGULAR MEETING, December 21, 1895.—Present: President George S. Webster, Vice-Presidents A. Falkenau and John L. Gill, Jr., Directors Edward K. Landis, C. L. Prince, Henry Leffmann, W. C. Furber, Wm. J. Hoyt, the Secretary and the Treasurer.

The Treasurer's Report for November showed:

Balance from October	$192 58	
Amount received during November	399 75	
		$592 33
Amount expended during November		226 26
Balance November 30th		$366 07

The Secretary reported the applications for membership, and the resignations on hand, and upon motion it was decided that the first Club meeting in January be a Business Meeting to act upon these.

A suggestion from Mr. Landis that a provision be made in the By-Laws for the reinstatement of members who had been dropped was discussed, and after a suggestion for an amendment to the By-Laws, the motion was made and carried that the chair appoint a Committee to present a revised form of Charter and By-Laws for the Club. The Chair appointed Messrs. Falkenau (chairman), Landis, Furber and Leffmann on this Committee.

Mr. Gill moved that the Secretary be authorized to confer with the former publishers of our List of Members, and with other parties, for publishing the list for 1896 in the same style, and that he also obtain prices for publishing the list without advertisements. Carried.

After a motion had been made that, as the electrical talks were concluded, the contract for current with the Edison Electric Light Company be cancelled, Mr. Hoyt read for the information of the Board the form of contract that had been signed by Mr. Pike for the Chairman of the House Committee, and by the Edison Company, and the above motion was withdrawn in favor of one by Mr. Furber that the Edison Company's terms for the Club in future be learned by the Secretary and reported to the Board at its next meeting. This motion was carried.

Mr. Prince called attention to the expense he had been put to in preparing lantern slides to illustrate papers read at Club meetings, and stated that in the future he would wish to be reimbursed at the rate of 15 cents for slides from negatives, with 15 cents additional where negatives had to be made by him. Upon motion, it was ordered that Mr. Prince be reimbursed for the lantern slides supplied to the Club from October 1st and not already paid for.

Upon motion, the Secretary was instructed to prepare a voting slip in future, containing only the names of applicants for election to membership, with instructions to voters, to be accompanied by a separate slip containing an abstract of the professional record of the applicants, with the names of their proposers.

The Board reappointed the Committee of Tellers for 1895 to serve during 1896.

The Board fixed salaries for 1896 as follows: For the Secretary, $20 per month; for the Treasurer, $5 per month; for the office assistant, $50 per month; for the janitress, $30 per month.

The Committee to audit the Treasurer's accounts was appointed, consisting of Messrs. H. C. Lüders, (chairman), Max Livingston and James Christie, with Mr. W. P. Dallett as alternate.

Upon motion, the President appointed a Special Committee, consisting of the Chairmen of the standing Committees of the Board, to prepare the Annual Report, and present the same for consideration at the Special Meeting of the Board of Directors on January 4, 1896.

CONTRIBUTIONS TO THE LIBRARY.

FROM OCTOBER 15 TO DECEMBER 15, 1895.

From AMERICAN INSTITUTE OF MINING ENGINEERS.

An Improved Form of Protractor for Mapping Mine-Surveys—Ayres.
Assay of Auriferous Ores and Gravels by Amalgamation and the Blow-Pipe—Leonard.
Biographical Notice of Eckley B. Coxe.
Biographical Notice of Franz Posepny.
Chrome in the Southern Appalachian Region—Glenn.
Eastern Coal Regions of Kentucky—MacFarlane.
Florida Pebble Phosphates—Codington.
Geological Structure of the Western Part of the Vermilion Range, Minnesota—Smyth & Finlay.
Gold Regions of Georgia and Alabama—Brewer.
Magnetic Separation of Iron Ore—Ball.
Nomenclature of Zinc Ores—Discussion.
Notes on Certain Water Worn Vein-Specimens—Holman.
Notes on the Magnetization and Concentration of Iron Ore—Phillips.
Present Condition of Gold Mining in the Southern Appalachian States—Nitze & Wilkens.
Proceedings of the Sixty-ninth Meeting, Atlanta, Georgia, October, 1895.
Section of Rich Patch Mountain at Iron Gate, Virginia—Schmitz.
Southern Coal-Washing Plant—Discussion.
Southern Magnetites and Magnetic Separation—Chase.
Tin Deposits of Durango—Discussion.

From DEPARTMENT OF INTERNAL AFFAIRS, HARRISBURG, PA.

Annual Report, 1894.
Part I.—Land Office, Boundary Lines, State Weather Service.
Part II.—Assessments, Taxes.
Part V.—Reports of Inspectors of Coal Mines.

From ENGINEERING NEWS.

Engineering Contracts and Specifications—Johnson.

From FIELD COLUMBIAN MUSEUM.

Annual Report of the Director, 1894–95.

From C. E. FOWLER.

General Specifications for Roofs and Iron Buildings.

From Geological Survey of Canada.

Eastern Townships Map—Quebec, N. E. Quarter Sheet.
Maps:
Antigonish Town Sheet, Nova Scotia—Sheet No. 34.
Cape George Sheet, Nova Scotia—Sheet No. 33.
Country Harbor Sheet, Nova Scotia—Sheet No. 30.
Gegogan Sheet, Nova Scotia—Sheet No. 28.
Guysborough Town Sheet, Nova Scotia—Sheet No. 25.
Isaac's Harbor Sheet, Nova Scotia—Sheet No. 27.
Liscomb River Sheet, Nova Scotia—Sheet No. 37.
Lochaber Sheet, Nova Scotia—Sheet No. 35.
Mosers's River Sheet, Nova Scotia—Sheet No. 38.
Pomquet Harbor, Nova Scotia—Sheet No. 32.
Roman Valley Sheet, Nova Scotia—Sheet No. 31.
Sherbrooke Sheet, Nova Scotia—Sheet No. 29.
West River St. Mary's Sheet, Nova Scotia—Sheet No. 36.
Whitehaven Sheet, Nova Scotia—Sheet No. 26.
Maps of the Principal Auriferous Creeks in the Cariboo Mining District, British Columbia, by Amos Bowman:
Placer Mines and Quartz Veins of Lightning Creek.
Placer Mines and Quartz Locations of Williams Creek.
Placer Mines of Antler Creek.
Placer Mines of Cunningham Creek.
Placer Mines of Harvey Creek.
Quartz Veins and Placer Diggings of Grouse Creek.
Quartz Veins and Placer Mines of Little Snowshoe and Keithley Creeks.
Section Along Harvey Creek.
Veins and Placer Mines of Sugar, Hardscrabble and Slough Creeks.
Rainy River Sheet—Ontario.
Sheet No. 11—S. W. Nova Scotia.

From William Paul Gerhard.

Sanitary Engineering.
The Rain Bath—A Novel Form of Bath and New Method of Bathing Insane Patients.

From Arata Hamao.

The Imperial University Calendar, Tokyo, Japan, 1894–95.

From Navy Department, Washington, D. C.

Annual Report of the Chief of the Bureau of Steam Engineering, 1895.

From Nova Scotian Institute of Science.

Proceedings and Transactions, Session of 1893–94.

From Rochester Academy of Science.

Brochure 4 of Volume II, 1895.

From State Board of Health of Massachusetts.

Twenty-sixth Annual Report, 1894.

From United States Coast and Geodetic Survey.

Report of Superintendent, 1893—Part II.

From University of Minnesota.

Year Book of Society of Engineers, May, 1895.

From University of Wisconsin.

Evolution of a Switchboard—Abbott.
Railway Signaling—Grafton.
Some Practical Hints in Dynamo Design—Wilkes.
Steel Construction of Buildings—Purdy.
Track—Loree.